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PREFACE

Bangladesh is the part of world's most dynamic hydrological and the biggest active delta system. The topography, location and outfall of the three great rivers shapes the annual hydrological cycle of the land. Too much and too little water in a hydrological cycle is the annual phenomenon. Regular monsoon event is the flood, the depth and duration of inundation are the deciding factors whether it affecting beneficially or adversely. Monsoon inflow along with rainfall historically shapes the civilization, development, environment, ecology and the economy of the country. Extreme events of flood adversely affect the development, economy, poverty and almost every sector. In flood management, Bangladesh has been taken structural and non-structural measures. One of the main non-structural measures is the flood forecasting and warning.

As stated in the BWDB Act-2000, Flood Forecasting in Bangladesh is the mandate and responsibility of Bangladesh Water Development Board (BWDB) and Flood Forecasting and Warning Center (FFWC) is being carried out this. The FFWC was established in 1972 and is fully operative in the flood season, from April to October every year, following the Standing Orders for Disaster (SOD) of the Government of Bangladesh. The FFWC is acting as the focal point in co-ordination with other ministries and agencies like BMD, DDM, DAE etc during the monsoon for flood disaster mitigation and management.

The objectives of flood forecasting and warning are to enable and persuade people and organizations to be prepared for the flood and take action to increase safety and reduce damage. Its goal is to alert the agencies/departments to enhance their preparedness and to motivate vulnerable communities to undertake preparedness and protective measures.

The professionals of FFWC gratefully acknowledge the valuable advice and leadership of Director General, BWDB for his interest, continuous drive and suggestion. The valuable suggestions and encouragement provided by the ADG (Planning), Chief Planning, Chief Engineer Hydrology and Superintending Engineer, Processing & Flood Forecasting Circle, BWDB to improve the quality of works of the center.

The services of Gauge Reader's, Wireless operators and other support service providers are gratefully acknowledged. The FFWC is also grateful to the print and electronic news media and those who helped in disseminating the flood information during flood 2012. A number of NGOs have been working in different areas for dissemination of the FFWC flood warning message at grass root level (Union and Village), this enables flood preparedness at local level.

With support from the Bangladesh Disaster Management Bureau (BMD), Cell Broadcasting (CB) has been started from July-2011 for flood warning message dissemination. Instant Voice Response (IVR) method is used; anyone can call 10941 from Teletalk mobile and hear a recorded Bangla Voice Message regarding days flood situation. As normal call charge applicable, the voice message is given within one minute duration. This method of innovative type disaster message dissemination is awarded in the Digital Innovation Fair 2011.

It is great pleasure that the regular observer of the FFWC web-site, noted by distinguished personalities at home and abroad is source of inspiration for improving the quality of services. Suggestion, feed-back and appreciation from policy level, ministries, different levels of GOs and NGOs is great encouragement of the professionals working in the FFWC. This is indeed a struggle and commitment to continue the services from April to October continuously, without week-ends and holidays. The FFWC with its very limited resources and manpower is working very hard to carry out the responsibility during the monsoon. The FFWC is trying to develop further the process and system to cope-up with the technological and computational development. One of the main struggle and demand is to increase flood forecasting and warning lead time.

The FFWC hopes that this report might be a point of interest to the planners, designers, administrators, working in the water sector, disaster managers/fighters and various activities of formulating measures for flood mitigation/management in Bangladesh. The FFWC warmly welcomes comments and suggestions; these would certainly improve the services, activities and output of the FFWC in the coming days.

Finally, I sincerely thank and acknowledge my colleagues of the FFWC whose earnest and sincere co-operation made it possible to publish this Annual Flood Report-2012.

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Executive Summary

The characteristics of flood of 2012, is a representative one in respect of duration and magnitude. During the monsoon 2012, the flood was not severe one, duration was short in the north (along the Brahmaputra-Jamuna River) and short to moderate in the part of north east. Duration of flooding in the central part(along the Padma river) was moderate. Duration of flooding in the south west, in the part of Satkhira and Khulna districts was prolong, due to slow drainage or very low carrying capacity of rivers, specially Kobodak, Haribhanga & Shibsa river system. Water Level of Kobodak River at Jhikorgacha flowed above danger level for 49 days. As a whole, the monsoon 2012 was a normal flood year. The evaluation indicated that the accuracy of deterministic flood forecasts issued by FFWC is around 92%, 85% and 79% for 24hrs, 48hrs and 72 hrs respectively for the monsoon of 2012.

The country as a whole received 24% less rainfall than normal during the monsoon-2012 (May to September). The Brahmaputra, Ganges, Meghna and South Eastern Hill basins received 34%, 31%, 24% and 10% less rainfall than the normal value respectively. During the monsoon-2012 all the basins recorded less rainfall than their respective normal during May-September period. The Meghna and South Eastern hill Basins recorded more rainfall than the normal value in June. Basin wise monthly percent less(-) or more(+) rainfall than the normal is presented in the following table.

The monthly rainfall recorded during June at Kanaighat exceeded the previous monthly maximum value of the station.

Month	Brahmaputra basin	Ganges basin	Meghna basin	SE Hill basin
May	-55.6%	-71.8%	-45.2%	-54.0%
June	-43.7%	-27.4%	+8.0%	+19.9%
July	-31.5%	-28.5%	-22.3%	-0.27%
August	-63.3%	-62.2%	-79.1%	-80.0%
September	-20.2%	-12.6%	-51.6%	-43.6%

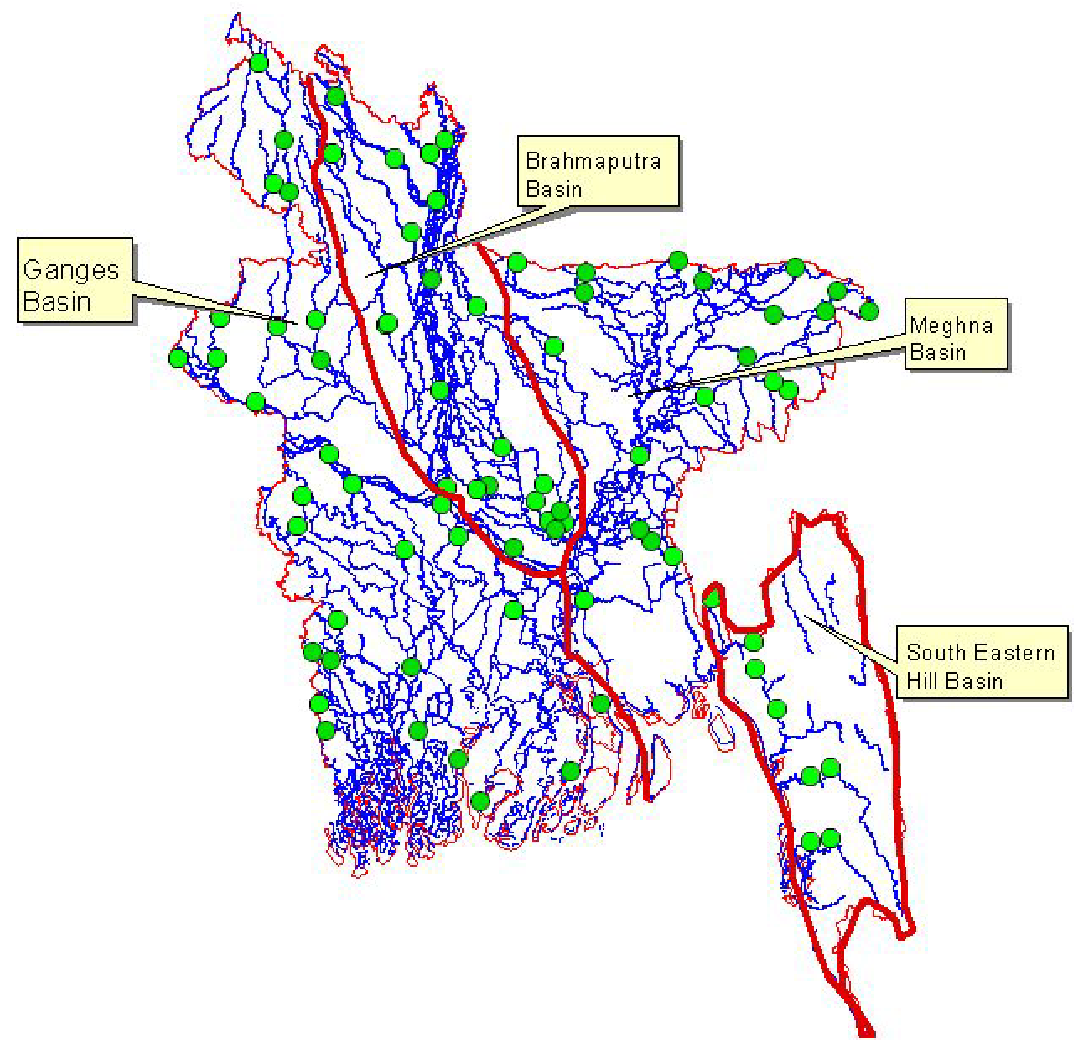
BWDB Data 2012

Professionals of the FFWC has been fully dedicated and committed to generate and disseminate flood forecasting and warning services despite of limited resources, technology, short of logistics and lack of professional staff.

During the monsoon-2012, maximum flooded area was 12% of the whole country (17,700 sq-km approximately). Some of the regions experienced river bank errosion and flash flood. The part of south west area flooded for prolong period.

List of Abbreviations

ADG	Additional Director General
ADPC	Asian Disaster Preparedness Centre
BWDB	Bangladesh Water development Board
BMD	Bangladesh Meteorological Department
CB	Cell Broadcast
CDMP	Comprehensive Disaster Management Programme
CEGIS	Centre for Environmental Geographical Information Services
CFAB	Climate Forecast Application Bangladesh
CARE	Cooperative for American Relief Everywhere
CFAN	Climate Forecast Application Network
DG	Director General
DL	Danger Level
DDM	Department of Disaster Management
DHI	Danish Hydraulic Institute
ECMWF	European Centre for Medium-Range Weather Forecasts
DEM	Digital Elevation Model
DAE	Department of Agriculture Extension
FFWC	Flood Forecasting and Warning Centre
GM	General Model
GBM	Ganges Brahmaputra Meghna
IWM	Institute of Water Modelling
IVR	Instant Voice Response
MAE	Mean Absolute Error
MoFDM	Ministry of Food and Disaster Management
MoWR	Ministry of Food Water Resources
NGO	Non-Government Organization
MSL	Mean Sea Level
RIMES	Regional Integrated Multi-hazard Early Warning System
SOD	Standing Order on Disaster
SSB	Single Site Band
SPARRSO	Space Research and Remote Sensing Organization
USAID	United States Agency for International Development
WL	Water Level



Basin Map of Bangladesh with Water Level Monitoring Stations

CHAPTER 1: INTRODUCTION

1.1. THE PHYSICAL SETTING

Bangladesh lies approximately between $20^o30'$ and $26^o40'$ north latitude and $88^o03'$ and $92^o40'$ east longitude. It is one of the biggest active deltas in the world with an area of about 1,47,570 sq-km. The country is under sub-tropical monsoon climate, annual average precipitation is 2,300 mm, varying from 1,200 mm in the north-west to over 5,000 mm in the north-east. India borders the country in west, north and most part of east. The Bay of Bengal is in the south, Myanmar borders part of the south-eastern area. It has 230 rivers including 57 transboundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna. Three rivers originated from Myanmar. Monsoon flood inundation of about 20% to 25% area of the country is assumed beneficial for crops, ecology and environment, inundation of more than that causing direct and indirect damages and considerable inconveniences to the population.

The country is mostly flat with only few hills in the southeast and the northeast part. Generally ground slopes of the country extend from the north to the south and the elevation ranging from 60 meters to one meter above Mean Sea Level (MSL) at the boundary at Tentulia (north) and at the coastal areas in the south. The land in the west of the Brahmaputra is higher than the eastern part. Several large depressions have been formed, particularly in greater Mymensingh, Sylhet and part of Pabna-Rajshahi districts. The country consists of the flood plains of the Ganges, the Brahmaputra and the Meghna rivers and their numerous tributaries and distributaries. The Ganges and the Brahmaputra join together at Aricha-Goalundo and is known as the Padma River. The river Meghna joining the Padma near Chandpur flows to the Bay of Bengal as the Meghna River.

1.2. THE RIVER SYSTEM

The Ganges, Brahmaputra and Meghna river systems together, drain the huge runoff generated from large area with the highest rainfall areas in the world. Their total catchment area is approximately 1.6 million sq-km of which only about 7.5% lies in Bangladesh and the rest, 92.5% lies outside the territory. It is assumed that an average flow of 1,009,000 Million cubic meters passes through these river systems during the monsoon season. Most of the rivers are characterized by having sandy bottoms, flat slopes, substantial meandering, banks susceptible to erosion and channel shifting. The river system of Bangladesh is one of the most extensive in the world, and the Ganges and the Brahmaputra are amongst the largest rivers on earth in terms of catchment size, river length and discharge.

The Brahmaputra (Jamuna) river above Bahadurabad has a length of approximately 2,900 km and a catchment area about 5,83,000 sq-km. Started from the glaciers in the northernmost range of the Himalayas and flows east far above half its length across the Tibetan plateau. In the complex mountain terrain bordering north-east India and China it bends through a series of gorges and is joined by a number of major tributaries, e.g., the Dihang and the Luhit before entering its broad valley section in Assam. This stretch is about 720 km long to the border of Bangladesh and throughout most of this, the course is braided. This braided channel is continued to the confluence with the Ganges.

Within Bangladesh, the Brahmaputra receives four major Right Bank tributaries - the Dudkumar, the Dharla, the Teesta and the Hurasagar. The first three are flashy rivers, rising in steep catchments on the southern side of the Himalayan between Darjeeling and Bhutan. The Hurasagar River is the outlet to the Karatoya-Atrai river system, which comprises much of the internal drainage of northwest of Bangladesh.

The Old Brahmaputra is the main left-bank distributaries of the Brahmaputra river presently known as the Jamuna. The shift of river course appears to have been taken place after a major earthquake and catastrophic flood in 1787. It is now a high flow spill river contributing largely to flood, as in the Dhaleswari, and their behavior is highly dependent on the variations of siltation at their entries.

Total length of the Ganges River is about 2,600 km to its confluence with the Brahmaputra -Jamuna at Aricha-Goalondo and a catchment area of approximately 9,07,000 sq-km. Started from the high western Himalayans glaciers, the Ganges has a short mountain course of about 160 km. From there it flows south easterly in a vast plain with major tributaries from the southern Himalayans in Nepal and smaller rivers from the central Indian Plateau to the south. With deep-water channel with numerous bar formations (chars), the Ganges is not braided. After its confluence with the Jamuna at Goalondo, the river, known as the Padma, flows in a wide and straight. At Chandpur, the Padma is joined to the Meghna from where it flows to the sea with tidal influence.

The Meghna system originates in the hills of Shillong and Meghalaya of India. The main source is the Barak River, which has a considerable catchment in the ridge and valley terrain of eastern Assam bordering Myanmar. On reaching the border with Bangladesh at Amalshid in Sylhet district, it bifurcates into Surma and the Kushiyara rivers. The Surma, flowing on the north of the Sylhet basin receives Right Bank tributaries from Khasia and Jaintia Hills of Shillong. These are steep, highly flashy rivers, originating in one of the wettest area of the world, the average annual rainfall at Cherrapunji at Assam being about 10,000 mm. The Kushiyara receives left bank tributaries from the Tripura Hills, the principal ones being the Manu. Also flashy in nature with less elevations and rainfall of Tripura makes these rivers less violent than the northern streams.

Between the Surma and Kushiyara, there are many internal draining depressions (haors), meandering flood channels and abandoned river courses, which are widely flooded every monsoon season. The two rivers rejoined at Markuli and flow via Bhairab as the Meghna to join the Padma at Chandpur. The major tributaries of any size outside the Sylhet basin are the Gumti and the Khowai River, which rises in Tripura and other hilly streams from Meghalaya and Assam of India to join the Meghna.

The streams of the southeast region are all short and of a flashy nature, rising in the Chittagong Hill Tracts or adjacent parts of eastern India. The main streams are the Muhuri, Halda, Sangu, Matamuhuri, etc.

1.3. ACTIVITIES OF FFWC

The importance of the flood forecasting and warning is widely recognized as a vital non-structural measures to aid the mitigating the loss of lives, crops and properties caused by the annual flood occurrence. The Flood Forecasting and Warning Centre, under the Directorate of Processing and Flood Forecasting Circle, Hydrology, BWDB carries out monitoring of 86 representative water level stations and 56 rainfall stations throughout the country. The principal outputs are the daily statistical bulletin of floods, river situation, a descriptive flood bulletin, forecast for 24, 48 & 72 hours about 52 monitoring points, production of Upazilla/Thana Status Map, Satellite Imageries, special flood report along with different graphical and statistical presentation during the monsoon season. The Centre is also involved in preparation of flood status report on National level, a weekly bulletin during dry season and monthly and annual flood reports. The Centre is responsible to act as a focal point in respect of flood from the month of April to November as per Government order for formulating the flood forecasts that are issued with the river situation bulletin and also provide support services to DDM, BMD and SPARRSO during cyclonic disaster.

Before 1990, forecast for six locations viz. Bahadurabad, Serajgonj, Aricha, Goalondo, Bhagyakul and Hardinge Bridge on the Padma – Brahmaputra –Jamuna system were issued by Co-axial correlation, Gauge to Gauge relation and Muskingum-Cunge Routing Model. After the devastating flood of 1987 and catastrophic flood of 1988, it was deeply realized that the forecast formulation should be introduced in the process of river modelling. In view of the above, the simulation model MIKE11 developed by Danish Hydraulic Institute (DHI) was installed at FFWC and a special version of MIKE11 FF conceptual Hydrodynamic model is in operation for forecast formulation.

The General Model (GM) developed under MIKE11 was adapted to real time operation in which boundary extended near to the Indian border on all main rivers. A supermodel now is in operational at FFWC covering entire flood affected area of Bangladesh, except coastal zone, the southern part.

The Supermodel covers about 82,000 km^2 of entire country, except the coastal zone of the country. The areas are sub-divided into 107 sub-catchments. It includes 195 river branches, 207 link channels, 40 Broad Crested Weirs. The total river length modeled is about 7300 km. Model operation and data base management, a well-managed server based (Widows 2000) LAN–Operating System has been installed with PCs at the FFWC.

1.4. OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

Data Collection: The real time hydrological data (73 WL stations and 56 rainfall stations) is collected by SSB wireless, fixed & mobile telephone from the BWDB hydrological network. WL for non-tidal stations are collected five times daily at 3 hourly intervals during day time from 6:00 AM to 6:00 PM, and for tidal stations collected hourly. Rainfall is collected daily period beginning at 9 AM. The data collections at FFWC are usually completed by 10:30 A.M. Limited WL, rainfall and forecasts of upper catchments from Indian stations are also collected through internet, e-mail, and from BMD.

Essential Information's: Estimation of WL at the model boundaries and rainfall for the catchments are required input to the model upto the time of Forecast (24h, 48h & 72h). For the rainfall estimation, satellite images from NOAA and IMD is used. In addition a dedicated land line radar link with BMD (Bangladesh Meteorological Department) provided frequent (five minutes interval) rainfall information.

Forecast Calculation: Collected/observed WL and rainfall data are given input to the computer database and checked. The WL and rainfall estimation has to be prepared. The basis for WL estimation is considering trend Hydrograph extrapolated upto the period of forecast from previous few days data, response characteristics of rivers, effect of rainfall on WL and Indian available WL & forecasts data. Rainfall estimation based on previous 2-day's rainfall and analysis of information collected. After input required data and boundary-estimated data to the model, model run started. It takes 30 to 40 minutes time to complete the calculations.

Daily forecast bulletin is prepared upto 72 hours for important locations and region-wise flood warning messages. The bulletins are disseminated to more than 600 recipients including different ministries, offices(central & district level), individuals, print & electronic news media, development partners, research oraganisations, NGO's etc. including President's & Prime Minister's Secretariat. Whenever, the forecast river stage cross the DL, the concern field offices and limited key officials are informed through mobile SMS. IVR through mobile has been initiated since July 2011 through Teletalk.

The flood forecast is intended to alert the people of the locality about the predicted WL of floodwater 3-days ahead of its occurrence. An accurate forecast would be one where the forecast level and corresponding observed level at the stipulated time are within a small range of variation.

1.5. NATURE AND CAUSES OF FLOODING

1.5.1. CAUSATIVE FACTORS

There are two distinct seasons, a dry season from November to April (or May) and the wet (flood) season from June to September (or October). Over 80% of the rainfall occurs during the monsoon or rainy season also known as flood season. The normal annual rainfall of the country varies approximately from 1,200 mm in the west to over 5,000 mm in the east. Long periods of steady rainfall persisting over several days are common during the monsoon, but sometimes local high intensity rainfall of short duration also occurs.

Floods in Bangladesh occur for number of reasons. The main causes are excessive precipitation, low topography and flat slope of the country; but others include:

- *The geographic location and climatic pattern:* Bangladesh is located at the foot of the highest mountain range in the world, the Himalayas, which is also the highest precipitation zone in the world. This rainfall is caused by the influence of the south-west monsoon. Cherapunji, highest rainfall in the world, is located a few kilometers north east of the Bangladesh border
- *The confluence of three major rivers, the Ganges, the Brahmaputra and the Meghna:* the runoff from their vast catchment (about 1.72 million km^2) passes through a small area, only 8% of these catchments lie within Bangladesh. During the monsoon season the amount of water entering Bangladesh from upstream is greater than the capacity of the rivers to discharge in to the sea.
- *Bangladesh is a land of rivers:* there are about 310 major and minor rivers in the country. The total annual runoff of surface water flowing through the rivers of Bangladesh is about 12,000 billion cubic meters.
- *Man-made environment:* the construction of embankments in the upstream catchments reduces the capacity of the flood plains to store water. The unplanned and unregulated construction of roads and highways in the flood plain without adequate opening creates obstructions to flow.
- *The influence of tides and cyclones*: the frequent development of low pressure areas and storm surges in the Bay of Bengal can impede drainage. The severity of flooding is greatest when the peak floods of the major rivers coincide with these effects.
- *Long term environmental changes:* climate changes could influence the frequency and magnitude of flooding. A higher sea level will inhibit the drainage from the rivers to the sea and increase the impact of tidal surges. Deforestation in hilly catchments causes more rapid and higher runoff, and hence more intense flooding.

The springtides of the Bay of Bengal retard the drainage of floodwater into the sea and locally increase monsoon flooding. A rise of MSL at times during the monsoon period due to effect of monsoon winds also adversely affect the drainage and raise the flood level along the coastal belt.

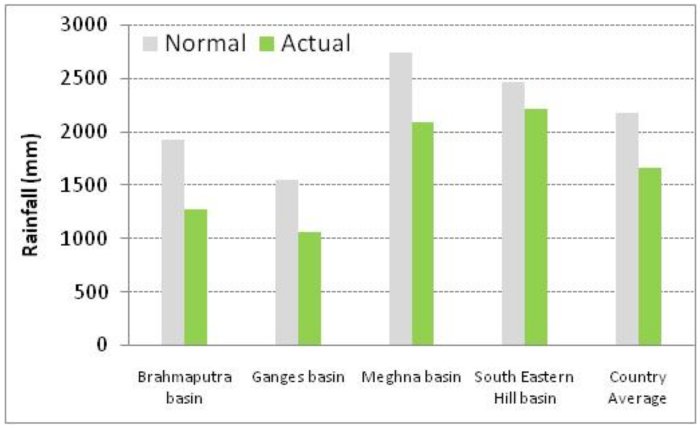
1.5.2. STATISTICS OF FLOODING

Many parts of the Asia during monsoon frequently suffer from severe floods. Some parts of India and Bangladesh experience floods almost every year with considerable damage. The floods of 1954, 1955, 1974, 1987, 1988, 1998, 2004 and 2007 all caused enormous damages to properties and considerable loss of life. The floods of 1987, 1988 1998, 2004 and 2007 flood caused heavy damage. During the monsoon 2012, the flood was not a severe one and stayed for short duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin. In the South Western part of the country experienced prolong flooding in few stations, longer then the previous flood years, specially part of Khulna, Jessore and Satkhira districts. During the monsoon-2012 other flood affected districts (part of full, on the low-lying areas) are Gaibandha, Serajgonj, Tangail, Jamalpur, Rajbari, Kushtia, Faridpur, Manikgonj, Munshigonj, Madaripur, Gopalgonj, Sariatpur, Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, Kishoregonj, Brahmmanbaria, Habigonj, Chandpur, Chittagong, Bandarban and Cox's Bazar. Percent of total area of Bangladesh affected by the flood are available since 1954 is presented in Table 1.1.

Table 1. 1 :Year-wise Flood Affected Area in Bangladesh

Year	Flood Affected area		Year	Flood affected area		Year	Flood affected area	
	Sq-Km	%		Sq-Km	%		Sq-Km	%
1954	36,800	25	1975	16,600	11	1995	32,000	22
1955	50,500	34	1976	28,300	19	1996	35,800	24
1956	35,400	24	1977	12,500	8	**1998**	**1,00,250**	**68**
1960	28,400	19	1978	10,800	7	1999	32,000	22
1961	28,800	20	1980	33,000	22	2000	35,700	24
1962	37,200	25	1982	3,140	2	2001	4,000	2.8
1963	43,100	29	1983	11,100	7.5	2002	15,000	10
1964	31,000	21	1984	28,200	19	2003	21,500	14
1965	28,400	19	1985	11,400	8	2004	55,000	38
1966	33,400	23	1986	6,600	4	2005	17,850	12
1967	25,700	17	1987	57,300	39	2006	16,175	11
1968	37,200	25	**1988**	**89,970**	**61**	**2007**	**62,300**	**42**
1969	41,400	28	1989	6,100	4	2008	33,655	23
1970	42,400	29	1990	3,500	2.4	2009	28,593	19
1971	36,300	25	1991	28,600	19	2010	26,530	18
1972	20,800	14	1992	2,000	1.4	2011	29,800	20
1973	29,800	20	1993	28,742	20	2012	17,700	12
1974	52.600	36	1994	419	0.2			

CHAPTER 2 : RAINFALL SITUATION



During the monsoon-2012 (May to Sept), the country experienced as a whole 23.6% less rainfall than normal. The Brahmaputra, Ganges, Meghna & South Eastern Hill & basins received 34%, 31%, 23.9% and 10.3% less rainfall than the normal value respectively. Comparison of the basin and country average of normal and actual rainfall for the monsoon-2012 (May to September) is presented in the bar chart. Considering monthly value, all the basins recorded less rainfall than their respective normal during May-September period. The Meghna and South Eastern hill Basins recorded more rainfall than the normal value in June. Monthly total normal and actual rainfall of all the basins and the country average of normal and actual monsoon rainfall is shown in Table 2.1.

Table 2.1: Rainfall statistics for the monsoon 2012 over the four Basins

Month	Brahmaputra Basin(mm)		Ganges Basin(mm)		Meghna Basin(mm)		South Eastern Hill Basin(mm)		Monsoon average (mm)	
	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual
May	315.4	139.9	191.8	54.9	491.0	269.0	290.4	133.6	2178.8	1664.0
June	433.5	301.7	327.0	256.6	621.0	675.0	599.8	748.7		
July	496.1	339.9	397.8	284.5	650.5	505.7	728.5	726.5		
August	339.7	215.0	337.8	210.0	537.9	425.3	536.9	429.7		
September	353.4	282.1	298.7	261.1	449.2	217.4	317.9	179.3		
Total	1938.1	1278.6	1553.1	1067.1	2749.6	2092.4	2473.5	2217.8		
% More/Less	34% less		31% less		23.9% less		10.3% less		23.6% less	

Rainfall situation of the country for the monsoon-2012(May to September) is described in the following sections.

2.1 MAY

Important Rainfall Information for May 2012

Monthly Maximum at Kanaighat 511.0 mm

1-day maximum at Dalia: 147.0 mm

10-day maximum at Sylhet: 299.0 mm

The country, as a whole, experienced rainfall less than normal during the month of May 2012. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill recorded 55.63%, 71.33%, 45.21% and 54.00% less rainfall than their respective monthly normal value. The summery of rainfall situation of the country during May 2012 is shown in the Table 2.2.

Table 2. 2 : Summary of the rainfall situation during the month of May 2012

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	12	17	12	11
Average Rainfall (mm) of the basin:	139.94	54.98	269.03	133.58
%More(+)/Less(-) than the Normal:	-55.63	-71.33	-45.21	-54.00
Number of Stations above Normal Rainfall:	0	0	0	0
Highest 1-day Maximum Rainfall with Stations:	Dalia (147mm)	Panchagarh (43.5mm)	Sylhet (103mm)	Noakhali (105.5mm)
Number of Rain Fed Flood* Stations:	0	0	0	0

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In Brahmaputra basin, out of 12 rainfall monitoring stations, 1 station recorded more rainfall than the normal and the other 11 stations received less rainfall than their normal of the month of May. The Basin received 55.63% less rainfall than their normal during the month May 2012.

In Ganges basin, out of 12 rainfall monitoring stations, all the stations received less rainfall than their normal value of the month. The basin as a whole received 71.33% less rainfall than the normal during the month of May-2012.

In the Meghna basin, out of 11 rainfall monitoring stations, all the stations recorded less rainfall than their normal value of the month. The Basin received 45.21% less rainfall than their monthly normal during the month of May 2012.

In the South Eastern Hill basin, all the rainfall monitoring stations received less rainfall than their normal rainfall. The basin as a whole recorded 54.0% less rainfall than the normal rainfall during the month of May 2012.

The Isohyets of the actual rainfall of the month of May-2012 is shown in the Figures 2.1.

2.2 JUNE

Important Rainfall Information for June, 2012
Maximum, at Kanaighat : 1453 mm
(exceeded previous monthly total rainfall)
1-day maximum, at Chittagong : 373.0 mm
10-day maximum, at Chittagong : 847.0 mm

The country, as a whole, recorded less rainfall than normal during the month of June-2012. The Brahmaputra and the Ganges basins recorded 43.66% and 27.44% less and the Meghna and South Eastern Hill basins recorded 8.0% and 19.89% more rainfall than their respective monthly normal rainfall during the month of June-2012. The summery of the rainfall situation for June 2012 is shown in the Table 2.3.

Table 2. 3: Summary of the rainfall situation during the month of June 2012

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	12	12	11	11
Average Rainfall (mm) of the basin:	301.733	256.575	675.05	748.73
%More(+)/Less(-) than the Normal:	-43.66%	-27.44%	+8.00%	+19.89%
Number of Stations above Normal Rainfall:	2	2	5	8
Highest 1-day Maximum Rainfall with Stations:	Kurigram **199.5 mm**	Panchagarh **178mm**	Kanaighat **282.0mm**	Chittagong **373mm**
Number of Rain Fed Flood* Stations:	2	2	6	10

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In the Brahmaputra basin, out of the 12 rainfall monitoring stations, 2 stations recorded more rainfall than normal value and all other 10 stations recorded less rainfall than the normal. The Basin received 43.66% less rainfall than the normal value during the month of June 2012.

In the Ganges basin, out of 12 rainfall monitoring stations, only 2 stations namely Panchagarh, and Khulna recorded more rainfall than the normal value and all the other 10 stations recorded less rainfall than their normal value of the month. The Basin received 27.44% less rainfall than their monthly normal during the month of June 2012.

In the Meghna basin, out of 11 rainfall monitoring stations, 6 stations recorded more rainfall than the normal value and all the other 5 stations received less rainfall than their normal value of the month. The basin as a whole received 8.00% more rainfall than the normal during the month of June-2012.

In the South Eastern Hill basin, all the rainfall monitoring stations received more rainfall than their normal rainfall, except Noakhali and Rangamati. The basin as a whole recorded 19.89% more rainfall than the normal rainfall during the month of June 2012 with maximum 1 day value of 373mm at Chittagong.

The Isohyets of the actual rainfall of the month of June-2012 are shown in the Figure 2.2.

2.3 JULY

<u>Important Rainfall Information for July 2012</u>
Maximum at Swandip: 1366 mm
1-day maximum at Lama: 373 mm
10-day maximum at Sunamganj: 847 mm

The country, as a whole, experienced rainfall less than normal during the month of July 2012. The Brahmaputra, the Ganges, the Meghna and South Eastern Hill basins received 31.5%, 28.48%, 22.26% and 0.27% less rainfall than their respective monthly normal value. The summery of the rainfall situation during the month of July 2012 is shown in the Table 2.4.

Table 2. 4: Summary of the rainfall situation during the month of July 2012

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	17	12	11
%More(+)/Less(-) than the Normal:	**-31.50%**	**-28.48%**	**-22.26%**	**-0.27%**
Number of Stations above Normal Rainfall:	0	1	0	4
Highest 1-day Maximum Rainfall with Stations:	Dalia **223mm**	Dinajpur **207mm**	Sunamganj **210mm**	Lama **297.0mm**
Number of Rain Fed Flood* Stations:	1	2	5	7
Name of Rain Fed Flood* Stations:	Dalia	Panchagarh Dinajpur	Kanaighat Sylhet Sunamganj Sheola Durgapur	Lama Sandwip Cox's Bazar Chittagong Ramgarh Narayanhat Panchpukuria

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In the Brahmaputra basin, all the stations received less rainfall than their normal. The Basin received 31.5% less rainfall than their normal during the month July 2012.

In the Ganges basin, all stations recorded less rainfall than their normal value of the month. The basin as a whole received 28.48% less rainfall than its normal during the month of July-2012.

In the Meghna basin, all the stations recorded less rainfall than their normal value of the month, except Sunamgonj and Habigonj. The Basin recorded 22.26% less rainfall than their normal during the month of July 2012.

In the South Eastern Hill basin, 4 stations recorded more rainfall than the normal value and all other rainfall monitoring stations received less rainfall than their normal rainfall. The basin as a whole received 0.27% less rainfall than its normal rainfall during the month of July 2012. The isohyets of the actual rainfall of July-2012 is shown in the Figure 2.3.

2.4 AUGUST

Important Rainfall Information for August 2012
Maximum at Swandip : 893.0 mm
1-day maximum at Lama: 225.0 mm
10-day maximum at Coxss Bazar: 569 mm

The intensity of rainfall in the Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basin was moderately low at most of the places during the month of August. All four hydrological basins of the country received less rain fall than their respective monthly normal during August, 2012. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basin received 63.3%, 62.2%, 79.1% and 80.04% less monthly rainfall than their respective normal rainfall. Considering the rainfall in the country, the August was the wet month of the monsoon-2012. Table 2.5 represents the summary of rainfall situation all through the country during August-2012.

Table 2. 5: Summary of the rainfall situation during the month of August 2012

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	12	11	11
Basin average rainfall at August,2012(mm):	215.04	210.05	425.35	429.75
%More(+)/Less(-) than Normal:	-63.3%	-62.2%	-79.1%	-80.04%
No. of Stations above Normal Rainfall:	2	0	2	3
Highest 1-day Maximum Rainfall Stations:	Gaibandha (180mm)	Patuakhali (91 mm)	Sunamganj (150 mm)	Lama (225 mm)
No of Rain Fed Flood* Stations:	0	0	2	3

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

The above table shows that 11 out of 13 stations in the Brahmaputra basin, all out of 12 stations in the Ganges basin, 9 out of 11 stations in the Meghna basin and 8 out 11 stations in South Eastern Hill the basin received less rainfall than their monthly normal rainfall. Among all monitoring stations, 1-day maximum rainfall was recorded at Swandip and 10-day consecutive maximum rainfall of 2514.7mm at Sunamganj was recorded during August-2012.

The Isohyets of the actual rainfall of the month of August-2012 is shown in the Figure 2.4.

2.5 SEPTEMBER

<u>Important Rainfall Information for September 2012</u>

Maximum at Sunamganj : 670.0 mm

1-day maximum at Khulna: 160.0mm

10-day maximum at Dalia: 482.0mm

The country, as a whole, experienced rainfall less than the normal value except the South Eastern Hill basin during the month, September 2012. Among the four hydrological basins of the country, the Brahmaputra, the Ganges and the Meghna and the South Eastern Hill basins received 20.16%, 12.56%, and 51.59% and 43.61% less rainfall basin received than their respective monthly normal rainfall during the September 2012. At Sunamganj the monthly maximum rainfall was recorded 670mm. Table 2.6 represents the summary of rainfall situation all through the country during the month of September 2012.

Table 2. 6: Summary of the rainfall situation during the month of September 2012

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	12	11	11
Basin average rainfall at September,2012(mm):	282.14	261.15	217.45	179.30
%More(+)/Less(-) than Normal:	-20.16%	-12.56%	-51.59%	-43.61%
No. of Stations above Normal Rainfall:	3	3	0	1
Highest 1-day Maximum Rainfall Stations:	Dalia (151 mm)	Khulna (160 mm)	Sunamganj (150 mm)	Ramgarh (85 mm)
No of Rain Fed Flood* Stations:	3	2	1	0
Name of Rain Fed Flood* Stations:	Dalia, Kaunia, Dewanganj	Panchagarh, Khulna	Sunamganj	-

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

The above table shows that 3 out of 13 stations in the Brahmaputra basin, 2 out of 12 stations in the Ganges basin, none of 11 stations in the Meghna basin and none of 11 stations in the South Eastern Hill basin received more rainfall than their monthly normal rainfall of September. Among all monitoring stations, 1-day maximum and 10-day consecutive maximum rainfall of 160.0mm and 482.0mm respectively were recorded at Khulna and Dalia respectively. The monthly maximum rainfall of 670.0mm was recorded at Sunamganj during September-2012.

The table also shows that all the 3 stations in Brahmaputra basin, 2 stations in the Ganges basin and 01 station in the Meghna Basin recorded more than 300 mm rainfall in consecutive 10-day period. As a result, Dalia, Kaunia, Dewanganj Panchagarh, Khulna and Sunamganj were affected by rain feed flood during September 2012. It may be mentioned here that 300 mm or more rainfall in 10-Day period may cause rain fed flood.

The Isohyets of actual rainfall for the month of August-2012 is shown in the Figure 2.5.

2.6 OCTOBER

<u>Important Rainfall Information for October 2012</u>

Monthly Maximum at Kanaighat : 586.0 mm

1 day maximum at Kanaighat: 549.0 mm

10 day maximum at Kanaighat: 300.0 mm

Among the four hydrological basins of the country, the Brahmaputra and the South Eastern Hill Basin received 51.17 % and 4.08% less rainfall than their monthly normal rainfall respectively during October-2012. The Ganges Basin and the Meghna Basin have been recorded respectively 1.53% and 41.62% more rainfall than the normal of October. At Kanaighat the monthly max rainfall recorded 586mm in October. The summary of the rainfall for the month of October-2012 is presented in Table 2.7

Table 2. 7: Summary of Rainfall for the month of October-2012

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	12	11	11
Average Rainfall (mm) of the basin:	75.47	131.83	275.73	190.86
%More(+)/Less(-) than the Normal:	**-51.17%**	**1.53%**	**41.62%**	**-4.08%**
Number of Stations above Normal Rainfall:	2	3	7	6
Highest 1-day Maximum Rainfall with Stations:	Dalia 130.0 **mm**	**Kushtia** 208.1**mm**	**Kanaighat** 300.**0mm**	**Chittagong** **1**13.**0mm**
Number of Rain Fed Flood* Stations:	0	1	4	2

***300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.**

The above table shows that 2 out of 13 stations in the Brahmaputra basin, 3 out of 12 stations in the Ganges basin, none of 7 stations in the Meghna basin and 6 stations out of 11 stations in the South Eastern Hill basin received more rainfall than their monthly normal rainfall of October. Among all monitoring stations, 1-day maximum and 10-day consecutive maximum rainfall of 300mm and 549mm respectively were recorded at Kanaighat in Sylhet. The monthly maximum rainfall of 586mm was recorded at Kanaighat during September-2012.

The table also shows that all the no stations in Brahmaputra basin, 1 station in the Ganges basin and 4 station in the Meghna Basin 2 stations in South East Hill Basin recorded more than 300 mm rainfall in consecutive 10-day period.

The Isohyets of actual rainfall for the month of August-2012 is shown in the Figure 2.6.

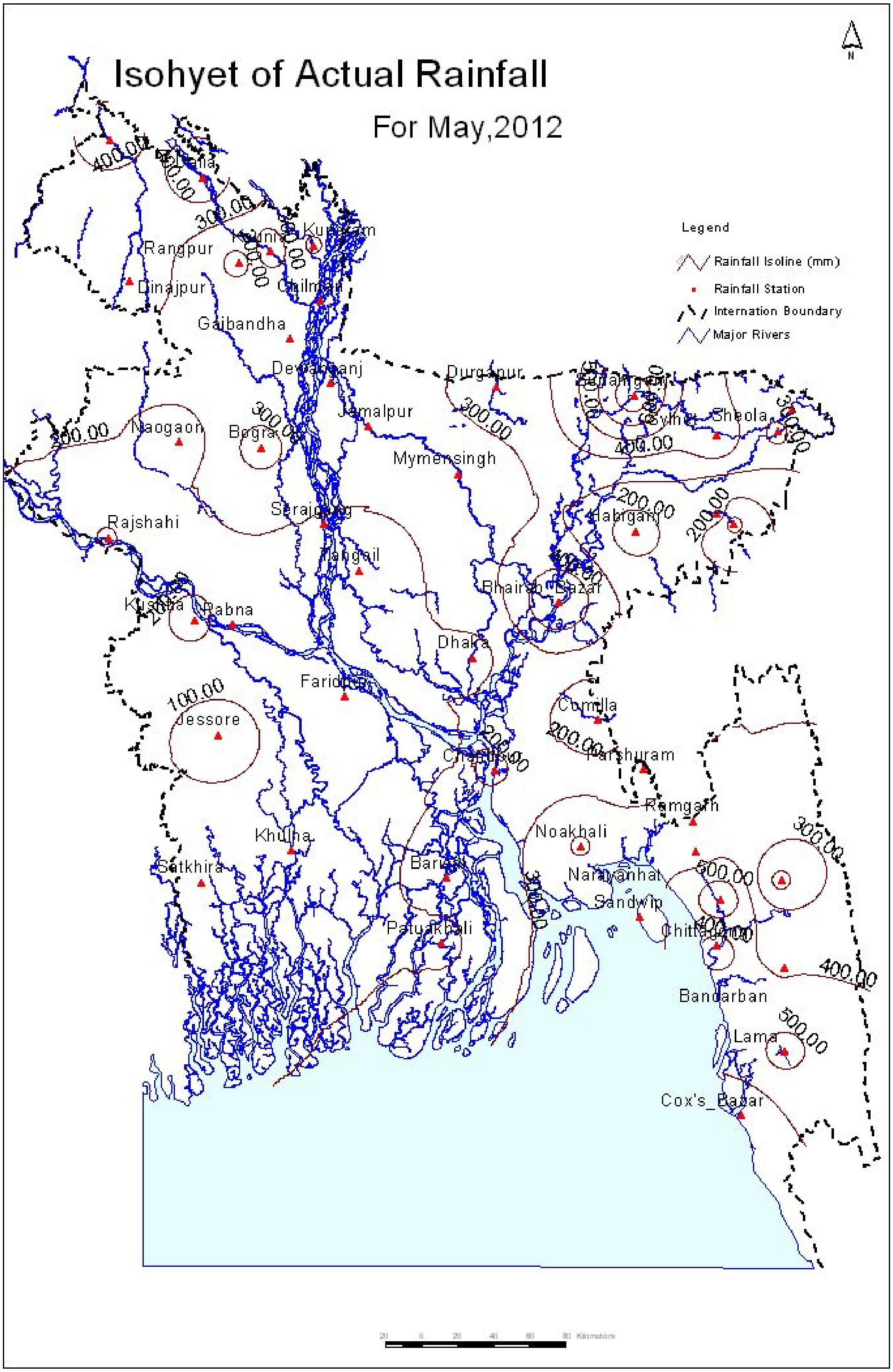


Figure 2.1 : Isohyets of Actual Rainfall (May 2012)

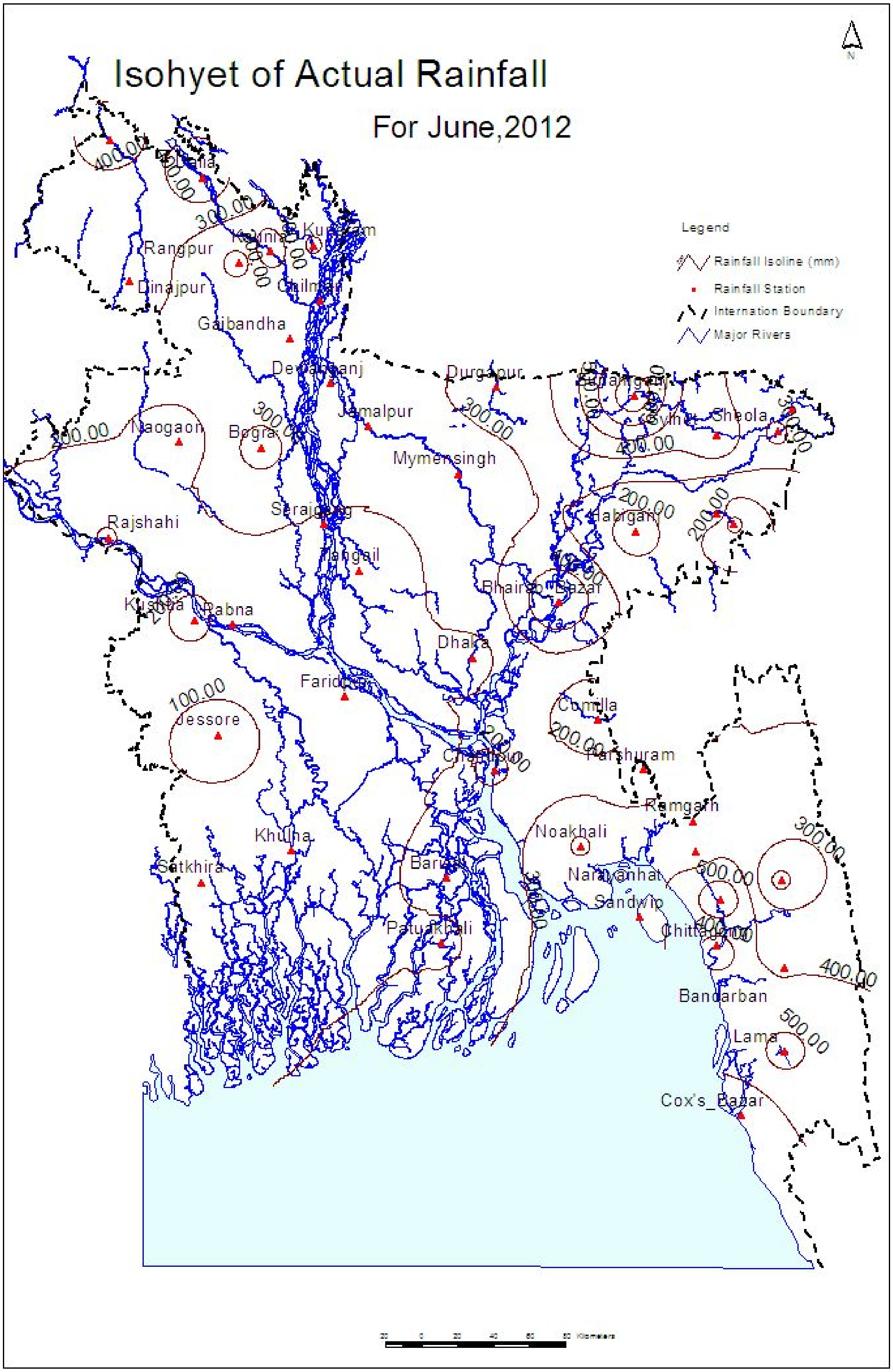


Figure 2.2 : Isohyets of Actual Rainfall (June 2012)

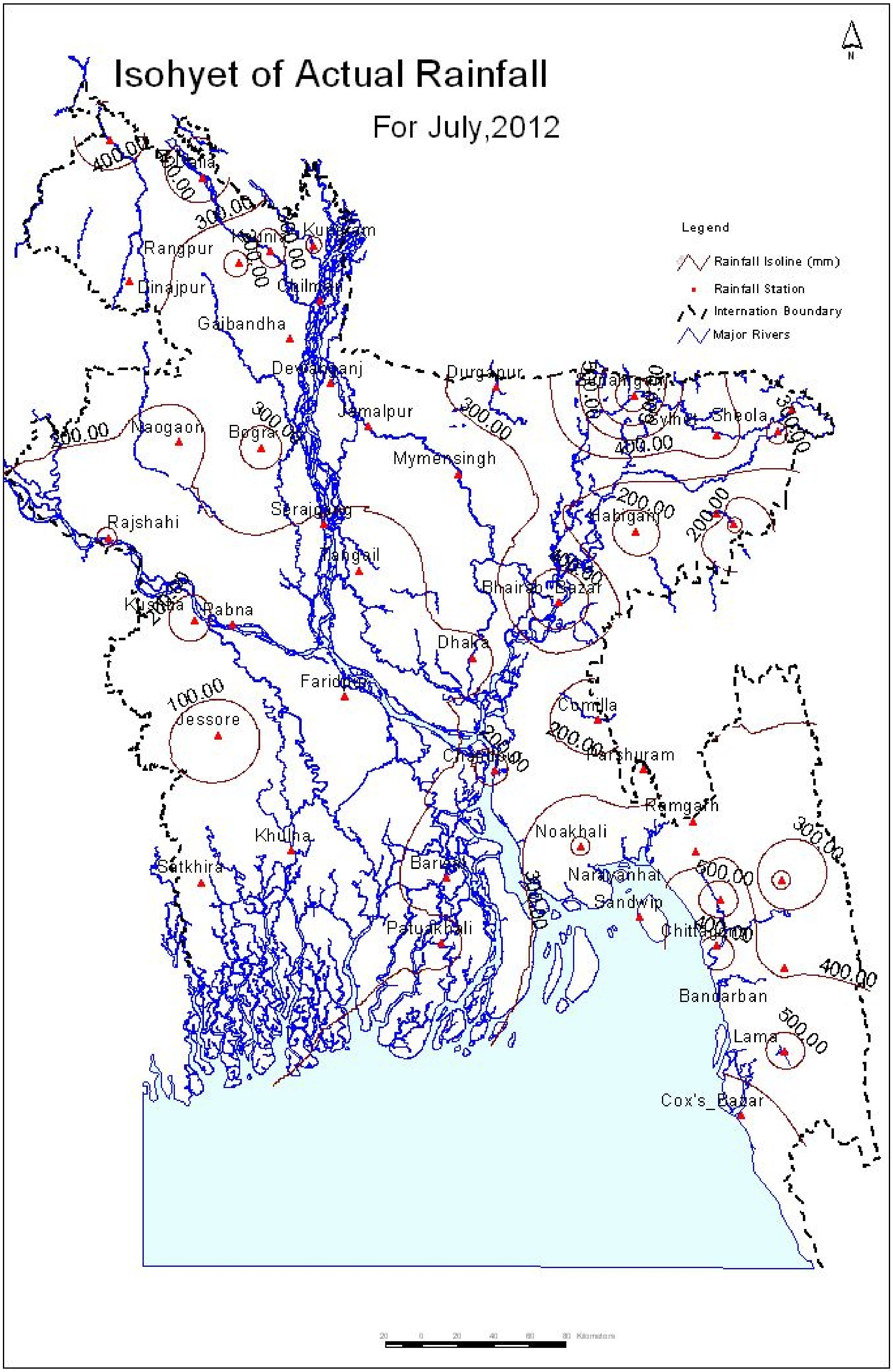


Figure 2.3 : Isohyets of Actual Rainfall (July 2012)

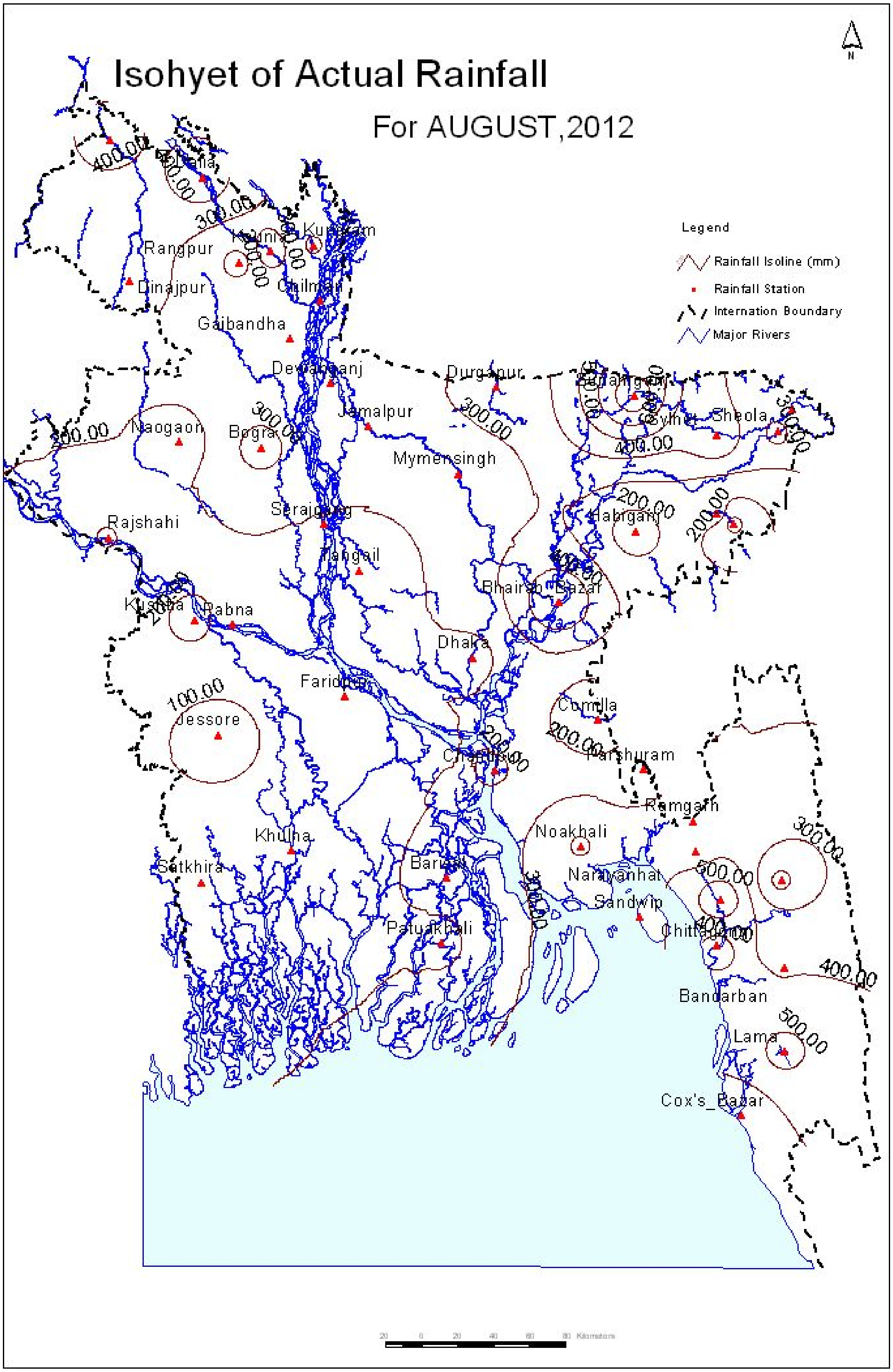


Figure 2.4 : Isohyets of Actual Rainfall (August 2012)

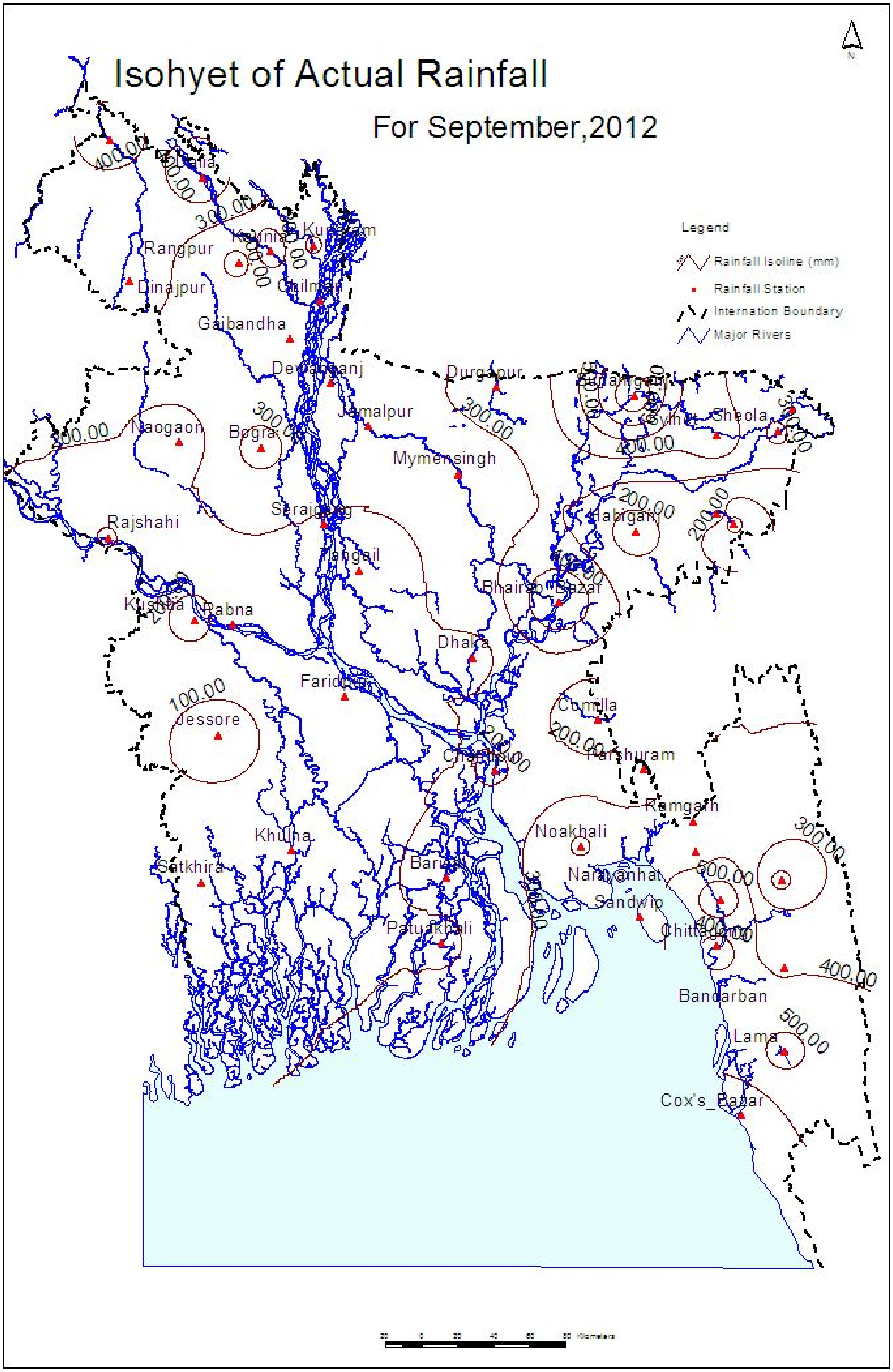


Figure 2.5 : Isohyets of Actual Rainfall (September 2012)

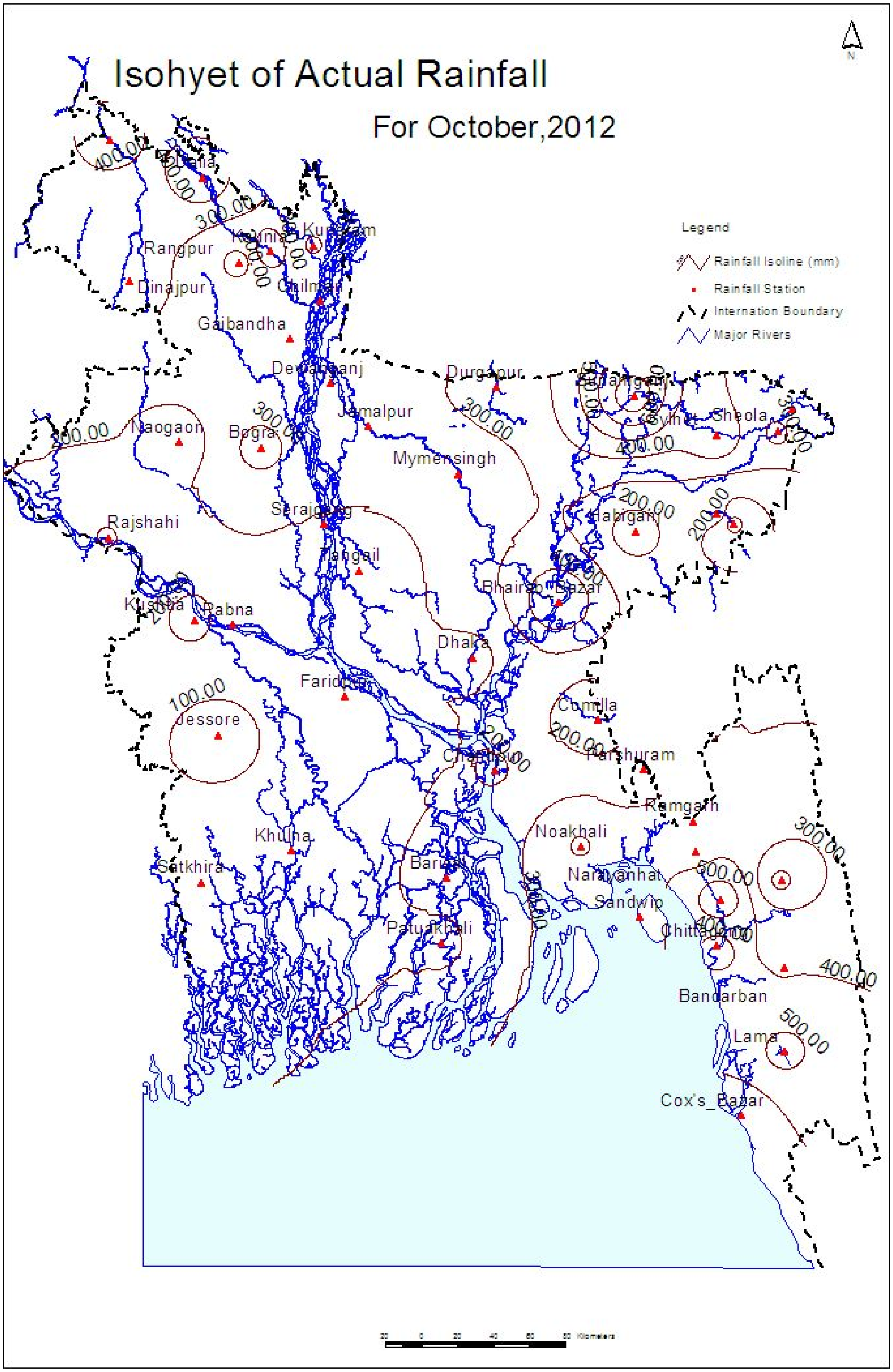


Figure 2.6 : Isohyets of Actual Rainfall (October 2012)

CHAPTER 3: RIVER SITUATION

During the monsoon 2012, the flood was not a severe one and stayed for short duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin, except few stations of the south west part of the country. The South Western part of the country experienced prolong flooding in few stations, longer then the previous flood years, specially part of Khulna, Jessore and Satkhira districts. Water Level at Jariajanjail on Kangsha was flowed above the danger level for continuous 30 days. During the monsoon-2012 there were flash floods affecting the Jariajanjail (in the North east, in Netrokona district) and Bandarban-Coxs Bazar(South east). Basin wise WL situation is described in the following sections.

3.1 THE BRAHMAPUTRA BASIN

Out of 23 Water Level (WL) monitoring stations in this basin, at 10 stations river WL was crossed their respective Danger Levels (DL), these are Bahadurabad on Jamuna river for 24 days and Serajgonj on Jamuna for 10 days and Gaibandha on Ghagot river for 15 days and Narayanganj on Lakhya river during July for 15 days, August and September. Other stations flowed above DL are Noonkhawa and Chilmari on Brahmaputra, Aricha on Jamuna, Badargonj on Jamunaeswari, Kurigram on Dharala, and Dalia on Teesta. As a result, low-lying areas of Kurigram, Lalminiorhat, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur and Narayangonj districts were flooded for short period. Height of flooding in the Brahmaputra river from Noonkhawa to Bahadurabad and Jamuneswari at Badargonj at the end of June is not like the previous flooding pattern. A comparative statement of WL for current year 2012 and historical events of 1988 and 1998 for the Brahmaputra Basin is shown in the Table 3.1. The details of the river situation in this basin are described in the following sections:

The Dharla at Kurigram

The WL of Dharla river at Kurigram registered two distinct peaks during the monsoon 2012, in June and July. It crossed the DL for three times during the monsoon and flowed above DL for 5 days. WL at Kurigram attained peak of 26.74mPWD on 29th June at 18:00 hours, which was 24cm above the DL (26.50 m), then fall of WL was recorded and again rise upto 26.68m (18cm above the DL) in the 3rd week of July.

The Teesta at Dalia and Kaunia

The Teesta river is flashy in nature. The WL of river Teesta showed several peaks during the monsoon both at Dalia and Kaunia. At Dalia WL crossed its DL mark for 5 times during the monsoon(twice in July and three times in September), highest peak on 16th July for one day only with peak of 52.70mPWD, which was 30cm above its DL (52.40m). At Dalia it flowed above DL for 9 days. At Kaunia WL of the river Teesta did not cross the DL during the mosoon-2012, attained the peak of 29.98m on 5th August which was 2cm below the DL(30.0m) at this point.

__The Ghagot at Gaibandha__

The WL of Ghagot river at Gaibandha crossed DL for three times. It flowed above the DL for 15 days during end of June and beginning of the July with peak of 22.35 m on 1st July, which was 65cm above its DL(21.70m) and again end of July and end of September.

__The Jamuneswari at Badargonj__

The Jamuneswari at Badargonj crossed the DL on 6 July at 18:00 hrs, attained the peak of 32.76mPWD(DL 32.16m), 60cm above the DL, on 8 July at 6:00 and 9:00 hours and flowed above DL for 6 days till 11 July at 12:00 hrs. At this point the river crossed the DL again on 16 September 06:00 hrs and attained the peak of 32.80m on 21 September during 15:00 hrs and 18:00 hrs and flowed above DL till 24 September 12:00 hours. At this point river flowed above the DL for 15 days.

__The Brahmaputra at Noonkhawa and Chilmari__

The river Brahmaputra at Noonkhawa and Chilmari observed sharp rise and fall at several times throughout the monsoon. At both the stations the river WL crossed the DL on the last week of June and again on the last week of September with a low water level at the middle of August, which is unusual. At Noonkhawa WL of the Brhamaputra river attained the peak of 27.6mPWD on 30 June at 06:00 hours, which was 35cm above the DL (27.25mPWD) at this point. At Chilmari the peak WL of the Brahmaputra river was recorded 24.48m on 30 June, which was 48cm above its DL(24.00m).

__The Jamuna at Bahadurabad, Serajgonj and Aricha__

The WL of river Jamuna at Bahadurabad, Serajgonj & Aricha demonstrated similar trends as Brahmaputra at Noonkhawa and Chilmari. At Bahadurabad the Jamuna flowed above DL three times for 23 days from 28 June to 4 July, again 16 July to 28 July and from 28 September to 01 October, with the peak of 20.56mPWD on 29 June, which is 106cm above the DL(19.50m) at this point. At Serajgonj the Jamuna flowed above DL in June for 3 days, July for 1 day and September for 6 days with peak of 13.98mPWD, on 29 September at 12:00hrs, which is 63cm above the DL(13.35m). At Aricha the WL of the Jamuna river crossed the DL with peak WL of 9.84mPWD on 30 September, which was 44cm above the DL(9.40m).

__The Old Brahmaputra at Jamalpur and Mymensingh__

The WL of the Old Brahmaputra river at Jamalpur and Mymensingh showed rise and fall during the monsoon, but remained below the respective DLs at both the stations. At Jamalpur the peak WL recorded of 16.70mPWD on 30th September which is 30cm below the DL at this point(DL 17.0m). At Mymensingh the peak WL recorded was 10.70mPWD on 27th July, which was180cm below the DL (12.5m) at this point.

The Lakhya at Narayangonj

The WL of Lakhya river at Narayangonj showed a similar trend to that of the Buriganga. At this point the Lakhya flowed above the DL during last part of July, begging of August and at the end of September for short period, with the peak of 5.66 mPWD, 16 cm above the DL (DL 5.50m) on 22 July at 12:00hrs.

The Rivers around Dhaka

Stations near or around Dhaka city like Buriganga at Dhaka, and the Turag at Mirpur attained the peak of the monsoon during the July in this year, mostly at end of the month. Flowed below their respective DLs. The Buriganga at Dhaka, the Balu at Demra and the Turag at Mirpur recoded their highest peak of 4.95 mPWD (DL 6.0m) on 23th July, 5.28m (DL 5.75m) on 23th July, 5.15mPWD (DL 5.94m) on 23th July respectively.

The Kaliganga at Taraghat

The WL of Kaliganga river at Taraghat showed a trend similar to that of the Buriganga at Dhaka. The river at this station remained below the DL throughout the season with peak of 8.18 m on 30th September, which was 22 cm below its DL(8.40 m) at Taraghat.

Comparative hydrographs for the year of 2012, 2004, 1998 & 1988 of few stations of the Brahmaputra basin are shown in Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 and 3.7.

Table 3. 1 : Comparison of Water Level of 2012 and Historical Events of 1988 & 1998 of Some Important Stations in the Brahmaputra Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					2012	1998	1988	12	98	88
1	Dharla	Kurigram	27.66	26.50	26.74	27.22	27.25	5	30	16
2	Teesta	Dalia	52.97	52.25	52.7	52.20	52.89	9	-	8
3	Teesta	Kaunia	30.52	30.00	29.98	29.91	30.43	-	-	38
4	Jamuneswari	Badargonj	33.00	32.16	32.76	33.00	32.80	15	6	5
5	Brahmaputra	Noonkhawa	28.10	27.25	27.6	27.35	NA	2	-	NA
6	Brahmaputra	Chilmari	25.06	24.00	24.48	24.77	25.04	8	22	15
7	Ghagot	Gaibandha	22.81	21.70	22.35	22.30	22.20	15	51	17
8	Jamuna	Bahadurabad	20.62	19.50	20.56	20.37	20.62	24	66	27
9	Jamuna	Serajgonj	15.12	13.75	13.98	14.76	15.12	10	48	44
10	Jamuna	Aricha	10.76	9.14	9.84	10.76	10.58	6	68	31
11	Old Br.putra	Jamalpur	18.00	17.00	16.7	17.47	17.83	-	31	8
12	Old Br.putra	Mymensingh	14.02	12.50	10.7	13.04	13.69	-	33	10
13	Buriganga	Dhaka	7.58	6.00	4.95	7.24	7.58	-	57	23
14	Lakhya	Narayangonj	6.71	5.50	5.66	6.93	6.71	15	71	36
15	Turag	Mirpur	8.35	5.94	5.15	7.97	NA	-	70	NA
16	Tongi Khal	Tongi	7.84	6.08	5.88	7.54	NA	-	66	NA

3.2 THE GANGES BASIN

In this basin out of 22 WL monitoring stations, 4 stations exceeded their respective DLs, during the monsoon 2012. The rivers flowed above DL are Ganges at Goalondo for 7 days, Padma at Bhagyakul for 11 days and Kobodak at Jhikorgacha for 49 days. The low lying areas of Rajbari, Faridpur, Manikgonj, Munshigonj, Sariatpur and Noagaon districts was affected by normal flooding during the month of June and August. Part of Satkhira, Jessore and Khulna districts was affected by prolong flooding during the September-October due to very poor drainage condition along with very high rainfall during September-October. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul and Goalundo. All other rivers, including the Ganges flowed below their respective DLs. A comparative statement of WL for 2012 and historical events of 1998 & 1988 for the Ganges Basin is shown in the Table 3.2. The details of the river WL situation in this basin are described below:

The Punarbhaba at Dinajpur

The WL of river Punarbhaba at Dinajpur showed sharp rise and fall during the monsoon, but did not cross the DL in the flood season of 2012. The peak WL of 32.85mPWD was recorded on 7th July, which was 65cm below its DL (33.50m).

The Upper Atrai at Bhusirbandar and Atrai at Modevpur

The WL of river Upper Atrai at Bhusirbandar (Upazila – Chirirbandar, District –Dinajpur) also showed similar trend of Punarbhaba, did not cross the DL. It had a peak value of WL 38.9mPWD on 8th July at 06:00hour, which was 72cm below the DL(39.62m). The Atrai at Mohadevpur (Noagaon District) flowed above DL for 2 days in 3rd week of June with peak of 19.85mPWD, which is 125cm above the DL(19.6m).

The Ganges/Padma at Pankha, Rajshahi and at Hardinge Bridge

The river at Pankha showed a gradual rise in the whole season of flood in 2012, but did not cross the respective DL. At Pankha the peak of 21.59m during the day of 24th of September, which is 91cm below the DL (22.50m) at this point. At Rajshahi and at Hardinge Bridge showed nearly similar trend as at Pankha and flowed below their respective DL throughout the monsoon-2012. It attained its peak of 17.87m on 26th September at 6:00 hours, which was 63cm below its DL (DL18.50m) at Rajshahi. At Hardinge Bridge; it attained its peak of 13.56m on 26th September, which was 69 cm below its DL (14.25m) at this point.

The Ganges/ Padma at Goalundo

At Goalondo river WL started to rise in month of September and it flowed around the DL, 6 times above the DL. The river at this point as a whole remained above its DL for 7 days. The WL of the river Padma at Goalondo attained its yearly peak of 9.17mPWD on the 29th September, which was 52 cm above its DL (8.65m) at this point.

The Padma at Bhagyakul

The river Padma has tidal influence at this point. At Bhagyakul, the WL of river Padma crossed the DL on 22-24 July for 2 days, 24 September to 02 October. The river at this point as a whole remained above its DL for 11 days. The WL of the river attained its highest yearly peak water level of 6.75 mPWD on 29th September, which was 45cm above the DL (6.30m) at Bhagyakul.

The Gorai at Gorai Railway Bridge and Kamarkhali

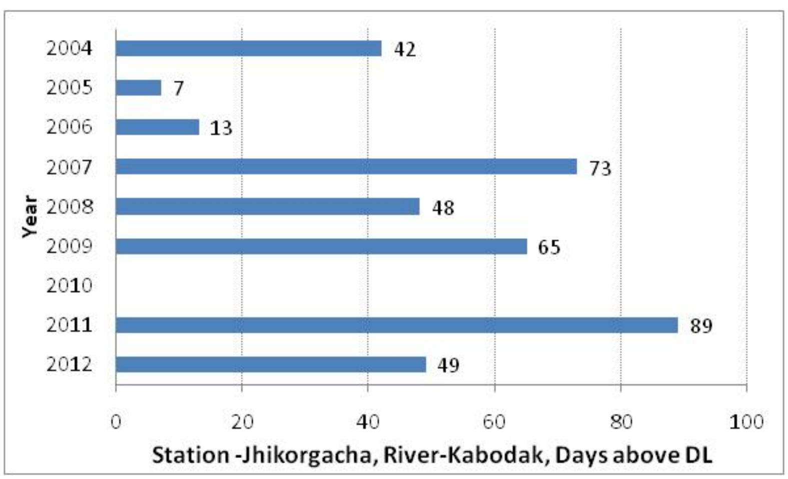
The WL of river Gorai at Gorai Railway Bridge and Kamarkhali showed steady rise during July to October. The WL of river Gorai did not cross the DL at Gorai Railway Bridge. The WL of the river attained its highest yearly peak of 12.09 mPWD on 27th of September, which was 66cm below the DL (12.75m) at Gorai Rail Bridge.

The Arialkhan at Madaripur

At Madaripur the WL of the river Arialkhan showed similar trend of rise and fall of the river Padma. The WL of Arialkhan at Madaripur did not flow above the DL. The WL attained its highest peak of 3.71 m on the 30th of September, which was 46cm below the DL (4.17m) at Madaripur.

Kobodak at Jhikorgacha

A prolong flooding situation was prevailed along the Kobodak river in September and October. At Jhikorgacha, the WL flowed above the DL for continuous 49 days with a peak of 4.39mPWD on 20th September, which was 28cm above the DL(4.11m) at this point and flowed above for 49 days. As a result, part of Satkhira, Khulna and Jessore districts were flooded for prolong period. This is due to the poor drainage condition and more rainfall in the region. At Jhikorgacha, the WL of river Kobodak crossed the DL on 9th September & remained above the DL till 26th of October. From the figure, it may be seen that, except 2010, the Kobodak flowed above its DL at Jhikorgacha in every year since 2004.



Comparative hydrographs for few important stations for the year of 2012, 2004, 1998 & 1988 of the Ganges basin are shown in figures 3.8 to 3.16.

Table 3 2 : Comparison of Water Level of 2012 and Historical Events of 1988 & 1998 of Some Important Stations in Ganges Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger Level		
					2012	1998	1988	2012	98	88
1	Punarbhaba	Dinajpur	34.40	33.50	32.85	34.09	34.25	-	3	4
2	Ganges	Pankha	22.97	25.50	21.59	24.14	NA	-	66	NA
3	Ganges	Rajshahi	20.00	18.50	17.87	19.68	19.00	-	28	24
4	Ganges	Hardinge Bridge	15.04	14.25	13.56	15.19	14.87	-	27	23
5	Padma	Goalundo	10.01	8.50	9.17	10.21	9.83	7	68	41
6	Padma	Bhagyakul	7.58	6.00	6.75	7.50	7.43	11	72	47
7	Gorai	Gorai Rail Bridge	13.65	12.75	12.09	13.45	13.65	-	25	25
8	Gorai	Kamarkhali	9.48	8.20	8.09	NA	NA	-	NA	NA
9	Arialkhan	Madaripur	5.80	4.17	3.71	NA	NA	-	NA	NA
10	Kobodak	Jhikorgacha	5.59	4.11	4.39	NA	NA	49	NA	NA

3.3 THE MEGHNA BASIN

Many rivers of this basin entered from the hilly catchment of India and are flashy in nature. Out of 20 WL monitoring stations in the Meghna basin, total 14 stations flowed above their respective DLs during the monsoon 2012, they are Kanaighat, Sylhet and Sunamgonj on Surma River, Amalshid, Sheola and Sherpur o Kushyara River, Jariajanjail on Kangsa, Mouolvi Bazar and Manu Rail Bridge on Manu river, Habigonj and Bullah on Khowai river, Kamalgonj on Dhalai river, Durgapur on Someswari river and Nakuakaon on Bhugai river. These stations flowed above their respective DLs for period of 1 day (Manu river at Manu Railway Bridge) to 35 days (Kangsha at Jariajanjail, Netrokona District). As a result, floods of short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, and Habigonj during the monsoon 2012.

Comparative statement of WL and days flowed above the DL for 2012 and historical events of 1998 and 1988 for this basin for selected stations are shown in Table 3.3.

The Surma at Kanaighat

As a flashy river, WL of the river Surma at Kanaighat (Sylhet district) showed several peaks during the monsoon-2012. WL flowed above its DL at Kanaighat during 1st week of June and flowed total 28 days above DL. It attained its highest peak of 15.58mPWD on 26th June at 12:00 hours, which was 238cm above the DL(13.20 m) at Kanaighat, exceeded the previous high WL recorded (previous record was 15.26mPWD).

Surma at Sylhet

The WL of river Surma at Sylhet flowed above DL for 10 days at the end of June and again mid of July in this monsoon with peak WL of 11.97mPWD on 27th June, which was 72cm above its DL (11.25m).

The Surma at Sunamgonj

The WL of the river Surma at Sunamgonj flowed above the DL for 21 days three times, in the month of June, July and August. The WL of Surma at Sunamgonj recorded its highest peak of 9.19mPWD on 16th July, which was 94cm above its DL (8.25m).

The Kushiyara at Amalshid

The river at this point observed several peaks during the monsoon 2012. It flowed above DL for 8 days at the end of June upto the first day of July (total 9 days). It attained the yearly peak of 17.89mPWD on 28th June at 18:00 hrs, which was 204cm above the DL (15.85mPWD) at Amalshid.

The Kushiyara at Sheola and Sherpur

The Kushiyara river at Sheola and Sherpur (Sylhet district) observed similar rise and fall as of Amalshid. At Sheola it flowed above the DL for 8 days in month of June and for 2 days during July (total 10 days). It attained its highest peak of 14.47 mPWD on 28th June at 6:00hrs, which was 97 cm above its DL (13.50 m). At Sherpur it flowed above the DL in June for 9 days and in July for 4 days (total 13 days). It attained its yearly highest peak of 9.28 m on 17th June, which was 28cm above its DL (9.00 m).

The Manu at Manu Railway Bridge and Moulvi Bazar

As a flashy river, the WL of the river Manu at Manu Railway Bridge (Moulvibazar district) and at Moulvibazar observed several peaks during the monsoon-2012. The WL of Manu river crossed the DL at Manu Railway Bridge(Moulvi Bazar district) for one day in June (peak 18.2mPWD, which is 113 cm above the DL). At Moulvi Bazar the WL of Manu flowed above DL for one day on 17th June attained the peak of 12.08mPWD, which was 33cm above its DL(11.75m) at this point.

The Someswari at Durgapur

As the flashy river the Durgapur in Netrokona district, showed several peaks during the monsoon 2012, remained above its DL for 10 days. It attained monsoon highest peak of 14.36mPWD on 23th September at 18:00hours, which was 136cm above its DL (13 m).

The Kangsha at Jariajanjail

As the flashy river the Kangsha at Jariajanjail in Netrokona district, it showed several peaks during the monsoon 2012, remained above its DL for 5 days in June from 25th to 30th June, for 20 days in July, for 8 days in August and for 2 days in September (total 35 days on or above the DL). It attained its yearly highest peak of 10.94 mPWD on 18th July at 09:00hours, which was 119cm above its DL (9.75m).

The Bhugai at Nakuagaon

As the flashy river the Bhugai at Nakuagaon in Sherpur district, recorded sharp rise and fall with several peaks during the monsoon 2012, flowed above its DL for 6 days. It attained monsoon highest peak of 24.2mPWD on mid July, which was 180cm above its DL (22.40m) at this point.

The Khowai at Habigonj and Bullah

As the flashiest river in Bangladesh, the Khowai at Habigonj showed several peaks during the monsoon 2012, The WL at Habigonj remained above its DL for 3 days in month of June. The WL recorded its yearly highest peak of 11.70 m on 17th June, which was 220 cm above its DL (9.50m). At Bullah the WL of Khowai flowed with peak of 24.45m on 1st June at 15:00 hours, which is 281cm above the DL (21.64m).

The Dhalai at Kamalgonj

The WL of the flashy river Dhalai at Kamalgonj flowed above its DL for 4 days in June, with monsoon peak of 20.65mPWD on 16th June at 18:00hours, which was 83cm above its DL(19.82m) at this point.

The Meghna at Bhairab Bazar

The WL of the Upper Meghna river at Bhairab Bazar flowed below its DL during the monsoon 2012, without much ups and downs from July to September. The peak WL recorded of 5.96mPWD on 24th July at 12:00 hours, which was 5cm below of its DL(6.0m) at this point.

Comparative hydrographs for few stations the year of 2012, 2004, 1998 & 1988 of rivers of the Meghna basin are shown in figures 3.17 to 3.30.

Table 3. 3: Comparison of Water Level of 2012 and Historical Events of 1988 & 1998 of Some Important Stations in Meghna Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					2012	**1998**	**1988**	**12**	**98**	**88**
1	Surma	Kanaighat	15.26	13.20	15.58*	15.00	15.10	28	73	75
2	Surma	Sylhet	11.95	11.25	11.97	11.72	11.95	10	14	21
3	Surma	Sunamgonj	9.46	8.25	9.19	8.90	9.03	21	56	62
4	Kushiyara	Amalshid	18.28	15.85	17.89	17.60	17.50	9	54	65
5	Kushiyara	Sheola	14.60	13.50	14.47	14.14	14.09	10	37	80
6	Kushiyara	Sherpur	9.68	9.00	9.28	NA	NA	13	NA	NA
7	Jariajanjail	Kangsha	13.37	9.75	10.94	NA	NA	35	NA	NA
8	Manu	Manu Railway Bridge	20.42	17.07	18.2	18.63	18.95	1	6	66
10	Manu	Moulvi Bazar	15.50	11.75	12.08	11.68	13.01	1	-	25
11	Khowai	Habigonj	12.00	9.50	11.7	11.44	11.06	3	8	14
12	Upper Meghna	Bhairab Bazar	7.66	6.25	5.96	7.33	7.66	-	68	68
13	Gumti	Comilla	13.56	10.38	10.6	12.79	11.80	-	17	17

***** At Kanaighat exceeded the previous recorded maximum WL.

3.4 THE SOUTH EASTERN HILL BASIN

The South Eastern Hill basin is constituted with the basin areas of the hilly rivers like the Muhuri, the Halda, the Sangu, the Matamuhuri and the Feni in the South Eastern Part of the country. The WL of the rivers Muhuri, Halda, Matamuhuri and Snagu crossed their respective DLs for 1 to 8 days during this monsoon-2012. As a result, a short duration flood occurred at Parsuram on Muhuri river, Narayanhat on Halda river, Dohazari on Sangu river, Chiringa and Lama on Matamuhuri river during the monsoon 2012. As a result, low lying areas of Chittagong, Bandarban and Cox's Bazar were affected by the flood for short duration. All other rivers of this basin flowed below their respective DLs. The details of WL of different river are described in following sections. A comparative statement of water level and days flowed above the DLs for the monsoon-2012 and historical events of 1998 and 1988 for this basin are shown in the Table 3.4.

The Muhuri at Parshuram

The Muhuri river in Feni, Noakhali district is a flashy one flowed above the DL in the month of June-2012. It attained its highest peak 13.9m on 24th June, which was 90cm above its DL (13.00 m).

The Halda at Narayanhat

The WL of the river Halda (a flashy river) at Narayanhat under Hathazari upzilla also showed several peaks during this monsoon. It crossed danger mark 6 times during the monsoon-2012, for two days in June, from 14th to 17th July for 4 days with peak of 17.05 mPWD (monsoon peak) on 15th July, which was 180 cm above the DL(15.25 m) at Narayanhat. The WL of the river Halda at Narayanhat flowed above the DL for 6 days in the monsoon-2012.

The Halda at Panchpukuria

The river here observed several peaks like Narayanhat, but flowed below its DL during the monsoon 2012. At Panchpukuria it attained its highest peak of 8.44mPWD on 18th July at 15:00 hours, which was 106 cm below its DL (9.50 m).

The Sangu at Bandarban

The river flowed above the danger mark on 25th June at 15:00 hours to 18:00 hours. The highest peak recorded was 16.4 mPWD on 25th June at 18:00 hours, which was 115 cm above its DL (15.25m).

The Sangu at Dohazari

The water level of river Sangu at this point also showed several peaks as of Bandarban flowed above the DL for three days only. The highest peak of the WL recorded at Dohazari of the river was 7.6m on 26th June at 06:00 hours, which was 60 cm above its danger mark (7.00 m) at this point.

The Matamuhuri at Lama

The river Matamuhuri at Lama observed several peaks and flowed over the danger level for two days on 26th June to 27th June in the monsoon. The highest peak recorded 14.65m on 27th June at 06:00 hours, which was 240cm above its DL(12.25m).

The Matamuhuri at Chiringa

The Muhuri at Chiringa recorded several peaks during the monsoon and flowed above the DL for 4 days on 24th June to 27th June, for 4 days on 13th, 14th, 17th and 18th July in this monsoon. It attained its yearly highest peak 7.82 m on 27th June at 06:00 hours, which was 207 cm above the DL (5.75 m).

The Feni at Ramgarh

The WL of river Feni at this point observed several peaks and flowed below its DL during the monsoon-2012. The highest peak WL attained by the river was 15.72 m on 15th July, which was 165cm below its DL (17.37m) at this point.

Table 3. 4 : Comparison of Water Level of 2012 and Historical Events of 1988 and 1998 of Some Important Station in South Eastern Hill Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					2012	98	88	2012	98	88
1	Muhuri	Parshuram	15.03	13.00	13.9	14.60	12.42	2	9	48
2	Halda	Narayanhat	18.05	15.25	17.05	16.57	NA	6	21	NA
3	Halda	Panchpukuria	11.55	7.00	8.44	10.44	10.05	-	4	6
4	Sangu	Bandarban	20.38	15.25	16.4	15.25	16.80	1	1	3
5	Sangu	Dohazari	9.05	5.75	7.6	7.42	NA	3	2	NA
6	Matamuhuri	Lama	15.45	12.25	14.65	13.05	12.18	2	2	-
7	Matamuhuri	Chiringa	6.83	5.75	7.82	6.85	NA	8	5	NA
8	Feni	Ramgarh	21.41	17.37	15.72	17.50	NA	-	1	NA

Comparative hydrographs for the year of 2012, 2004 and 1998 of few stations of the South Eastern Hill Basin are shown in Figures 3.31 to 3.36.

3.5 RECORDED HIGHEST WATER LEVEL

Table 3. 5: Recorded Peak Water Level with Date during the monsoon 2012

SL No	River name	Station	Peak WL-2012 (m)	Date
	BRAHMAPUTRA BASIN			
1	DHARLA	KURIGRAM	26.74	29/06/2012
2	TEESTA	DALIA	52.70	16/07/2012
3	TEESTA	KAUNIA	29.98	05/08/2012
4	JAMUNESWARI	BADARGANJ	32.85	20/09/2012
5	GHAGOT	GAIBANDHA	22.35	01/07/2012
6	KARATOA	CHAK RAHIMPUR	20.33	24/09/2012
7	KARATOA	BOGRA	13.68	18/09/2012
8	BRAHMAPUTRA	NOONKHAWA	27.6	30/06/2012
9	BRAHMAPUTRA	CHILMARI	24.48	27/09/2012
10	JAMUNA	BAHADURABAD	20.56	30/06/2012
11	JAMUNA	SERAJGONJ	13.98	28/09/2012
12	JAMUNA	ARICHA	9.84	28/09/2012
13	OLD BRAHMAPUTRA	JAMALPUR	16.7	30/09/2012
14	OLD BRAHMAPUTRA	MYMENSINGH	10.7	27/07/2012
15	BURIGANGA	DHAKA	4.95	23/07/2012
16	BALU	DEMRA	5.28	23/07/2012
17	LAKHYA	NARAYANGONJ	5.66	23/07/2012
18	TURAG	MIRPUR	5.15	25/07/2012
19	TONGI KHAL	TONGI	5.88	26/07/2012
20	KALIGANGA	TARAGHAT	8.14	30/09/2012
21	DHALESWARI	JAGIR	7.6	30/07/2012
22	DHALESWARI	REKABI BAZAR	4.86	24/07/2012
23	BANSHI	NAYARHAT	17.05	15/07/2012
	GANGES BASIN			
24	KARATOA	PANCHAGARH	70.2	16/09/2012
25	PUNARBHABA	DINAJPUR	32.85	07/07/2012
26	ICH-JAMUNA	PHULBARI	28.01	07/07/2012
27	TANGON	THAKURGAON	49.77	07/07/2012
28	UPPER ATRAI	BHUSIRBANDAR	38.9	08/07/2012
29	MOHANANDA	ROHANPUR	20.45	26/09/2012
30	MOHANANDA	CHAPAI-NAWABGANJ	20.28	25/09/2012
31	LITTLE JAMUNA	NAOGAON	14.45	21/07/2012
32	ATRAI	MOHADEBPUR	17.63	08/07/2012
33	GANGES	PANKHA	21.59	24/09/2012
34	GANGES	RAJSHAHI	17.87	26/09/2012
35	GANGES	HARDINGE BRIDGE	13.56	26/09/2012
36	PADMA	GOALONDO	9.17	29/09/2012
37	PADMA	BHAGYAKUL	6.75	29/09/2012
38	GORAI	GORAI RAIL BRIDGE	12.09	27/09/2012
39	GORAI	KAMARKHALI	8.09	27/09/2012
40	ICHAMATI	SAKRA	3.67	06/07/2012
41	MATHABHANGA	CHUADANGA	8.94	28/09/2012
42	MATHABHANGA	HATBOALIA	11.36	27/07/2012
43	KOBADAK	JHIKORGACHA	4.39	20/09/2012
44	KUMAR	FARIDPUR	4.58	30/09/2012
45	ARIALKHAN	MADARIPUR	3.71	30/09/2012

SL No	River name	Station	Peak WL-2012 (m)	Date
	MEGHNA BASIN			
46	SURMA	KANAIGHAT	15.58	26/06/2012
47	SURMA	SYLHET	11.97	27/06/2012
48	SURMA	SUNAMGONJ	9.19	16/07/2012
49	KUSHIYARA	AMALSHID	17.89	28/06/2012
50	KUSHIYARA	SHEOLA	14.47	28/06/2012
51	KUSHIYARA	SHERPUR	9.28	17/06/2012
52	SARIGOWAIN	SARIGHAT	14.22	26/06/2012
53	MANU	MANU RAILY BRIDGE	18.2	17/06/2012
54	MANU	MOULVI BAZAR	12.08	17/06/2012
55	KHOWAI	BALLAH	24.45	01/06/2012
56	KHOWAI	HABIGONJ	11.7	17/06/2012
57	DHALAI	KAMALGONJ	20.65	16/06/2012
58	BHUGAI	NAKUAGAON	24.2	17/07/2012
59	JADUKATA	LORERGARH	10.19	21/08/2012
60	SOMESWARI	DURGAPUR	14.36	23/09/2012
61	KANGSHA	JARIAJANJAIL	10.94	18/07/2012
62	MEGHNA	BHAIRAB BAZAR	5.96	24/07/2012
63	GUMTI	COMILLA	10.6	25/06/2012
64	GUMTI	DEBIDDAR	6.75	26/06/2012
65	MEGHNA	CHANDPUR	4.95	07/08/2012
	SOUTH EASTERN HILL BASIN			
66	MUHURI	PARSHURAM	13.9	24/06/2012
67	HALDA	NARAYAN HAT	17.05	15/07/2012
68	HALDA	PANCHPUKURIA	8.44	18/07/2012
69	SANGU	BANDARBAN	16.4	25/06/2012
70	SANGU	DOHAZARI	7.6	26/06/2012
71	MATAMUHURI	LAMA	14.65	27/06/2012
72	MATAMUHURI	CHIRINGA	7.82	27/06/2012
73	FENI	RAMGARH	15.72	15/07/2012

Table 3. 6: Recorded Historical Highest Water Level with Date

Sl. No.	River	Station	Danger Level (m)	Recorded highest WL (m) before 2012 flood (date)	WL (Date) Exceeding previous Highest WL (m)
1	Dharla	Kurigram	26.50	27.66 (14.07.96)	-
2	Teesta	Dalia	52.40	52.97 (29.07.72)	-
3	Teesta	Kaunia	30.00	30.52 (06.01.68)	-
4	Brahmaputra	Noonkhawa	27.25	28.10	-
5	Brahmaputra	Chilmari	24.00	25.07 (23.08.62)	-
6	Jamuna	Bahadurabad	19.50	20.62 (30.08.88)	-
7	Jamuna	Serajgonj	13.35	15.12 (30.08.88)	-
8	Jamuna	Aricha	9. 40	10.76 (02.09.88)	-
9	Old Brhamaputra	Jamalpur	17.00	18.00 (31.07.54)	-
10	Old Brhamaputra	Mymensingh	12.50	13.71(1.09.88)	-
11	Buriganga	Dhaka	6.00	7.58 (04.09.68)	-
12	Lakhya	Narayangonj	5.50	6.93 (10.09.98)	-
13	Turag	Mirpur	5.94	8.35 (10.09.88)	-
14	Tongi Khal	Tongi	6.08	7.84 (01.09.62)	-

15	Kaliganga	Taraghat	8.38	10.37(2.09.88)	-
16	Punarbhaba	Dinajpur	33.50	34.40	-
17	Padma	Pankha	21.50	24.14 (07.09.97)	-
18	Padma	Rajshahi	18.50	20.00 (13.09.1910)	-
19	Padma	H- Bridge	14.25	15.19 (10.09.98)	-
20	Padma	Goalundo	8.50	10.21 (03.08.08)	-
21	Padma	Bhagyakul	6.00	7.58	-
22	Gorai	Gorai Rly Br	12.75	13.65 (02.09.98)	-
23	Surma	Kanaighat	13.20	15.26	-
24	Surma	Sylhet	11.25	12.44 (19.07.04)	-
25	Surma	Sunamgonj	8.25	9.75 (20.07.04)	-
26	Kushiyara	Amalshid	15.85	18.28 (08.06.74)	-
27	Kushiyara	Sheola	13.50	14.60 (09.09.08)	-
28	Manu	Manu Rly Br	18.00	20.42 (23.05.02)	-
29	Manu	Moulvi Bazar	11.75	13.25 (8.06.93)	-
30	Khowai	Habigonj	9.50	12.00 (18.06.07)	-
31	Upper Meghna	Bhairab Bazar	6.25	7.78 (24.07.04)	-
32	Gumti	Comilla	11.75	13.56 (23.07.93)	-
33	Muhuri	Parshuram	13.00	16.33 (13.09.04)	-
34	Halda	Narayanhat	15.25	19.30 (13.08.99)	-
35	Halda	Panchpukuri a	7.00	12.54(27.06.03)	-
36	Sangu	Bandarban	15.25	20.7 (12.07.97)	-
37	Sangu	Dohazari	5.75	9.05	-
38	Matamuhuri	Lama	12.25	15.46 (12.08.99)	-
39	Matamuhuri	Chiringa	5.75	7.03 (10.07.97)	-
40	Feni	Ramgarh	17.37	21.42 (11.07.68)	-

WL - Water Level

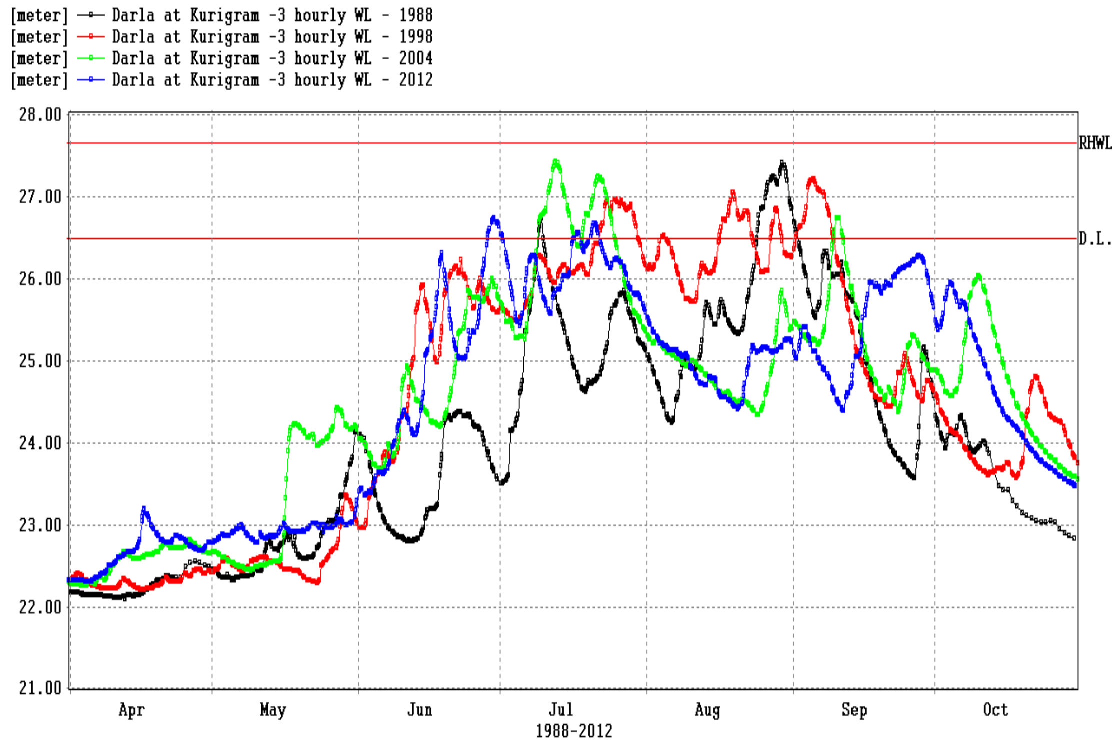


Figure 3.1 : Comparison of Hydrograph on Dharla at Kurigram

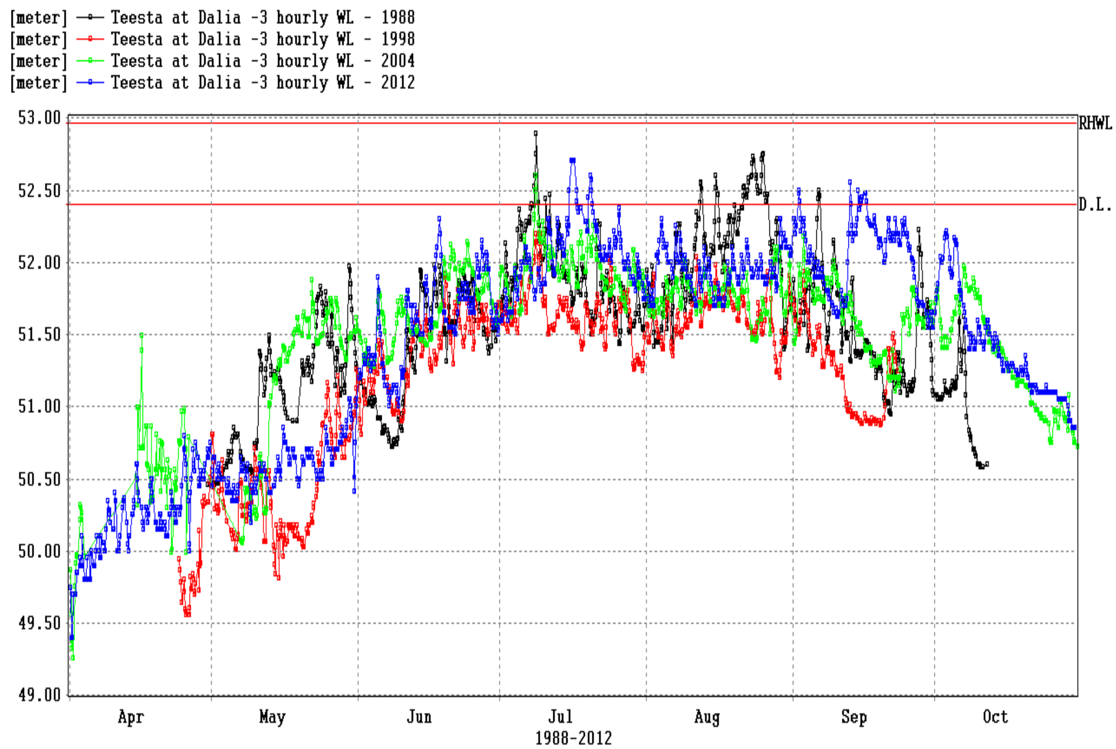


Figure 3.2 : Comparison of Hydrograph on Teesta at Dalia

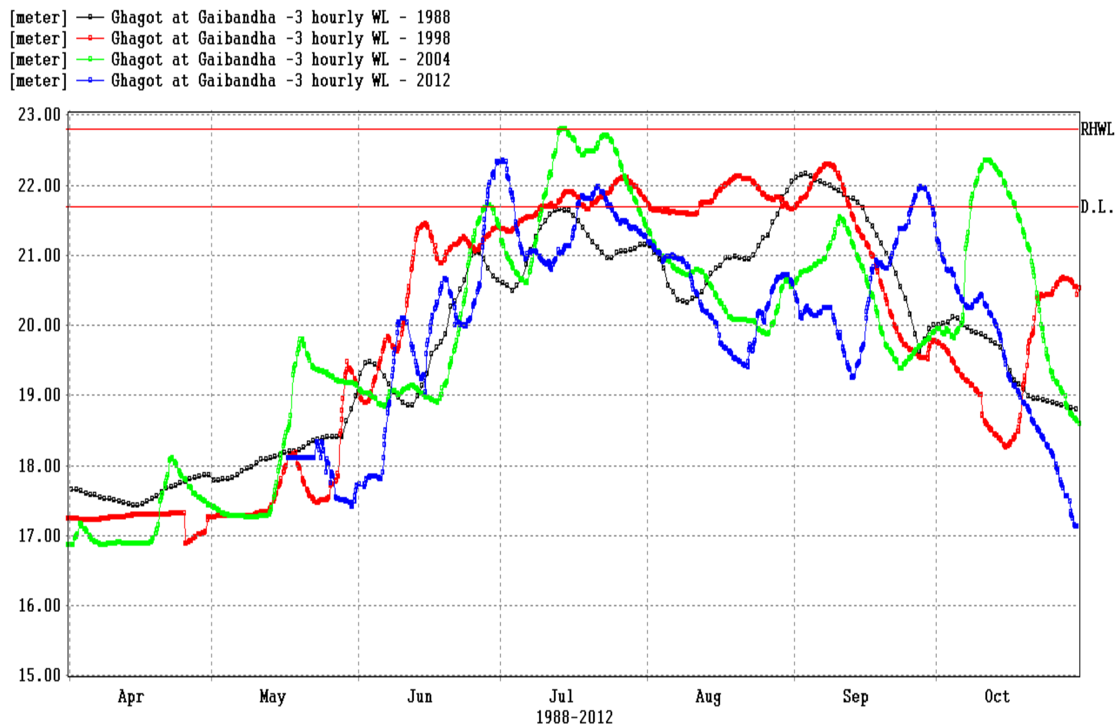


Figure 3.3 : Comparison of Hydrograph on Ghagot at Gaibandha

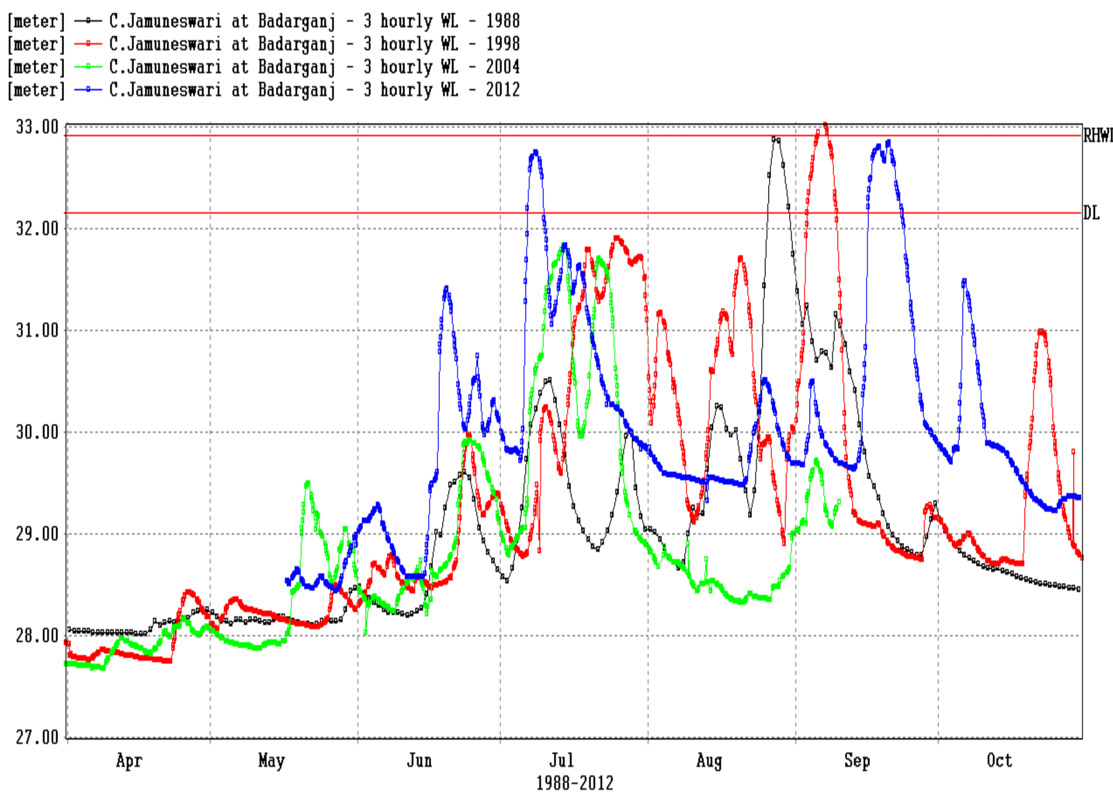


Figure 3.4 : Comparison of Hydrograph on Jamunesweri at Badargonj

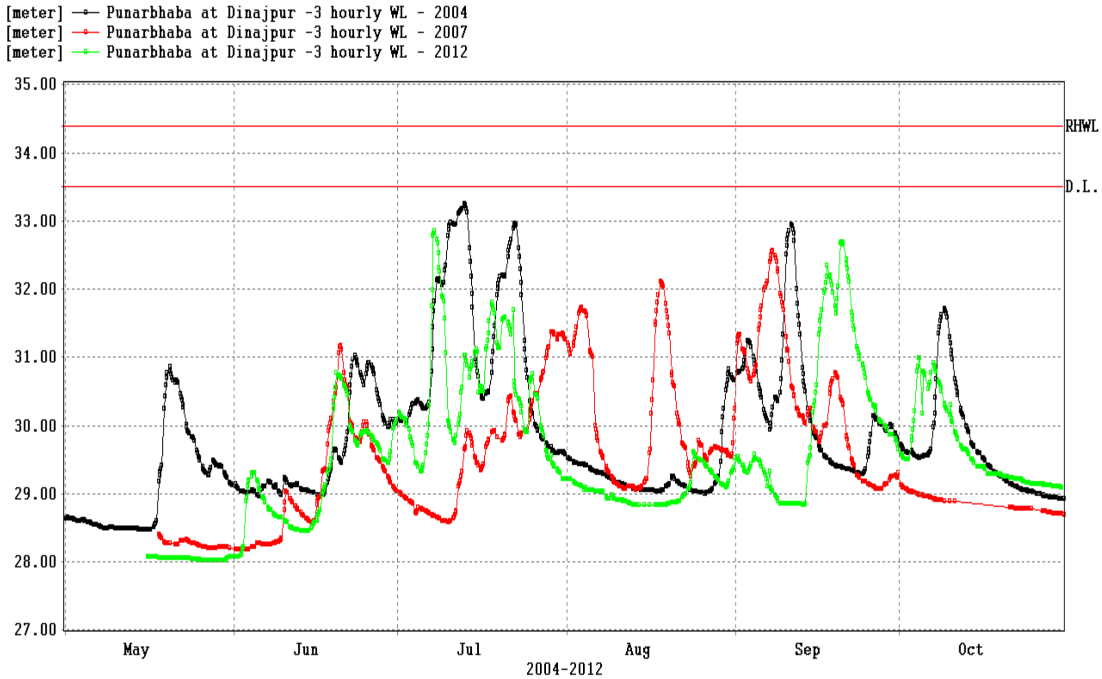


Figure 3.5 : Comparison of Hydrograph on Punurbhoba at Dinajpur

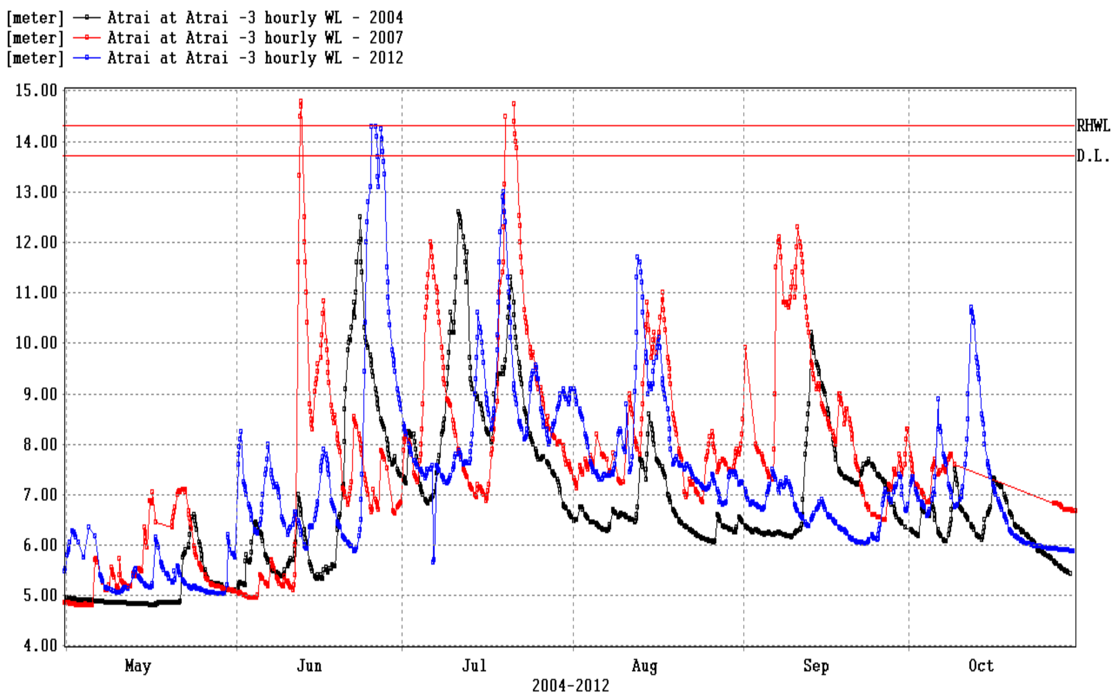


Figure 3.6 : Comparison of Hydrograph on Atrai at Mohadevpur

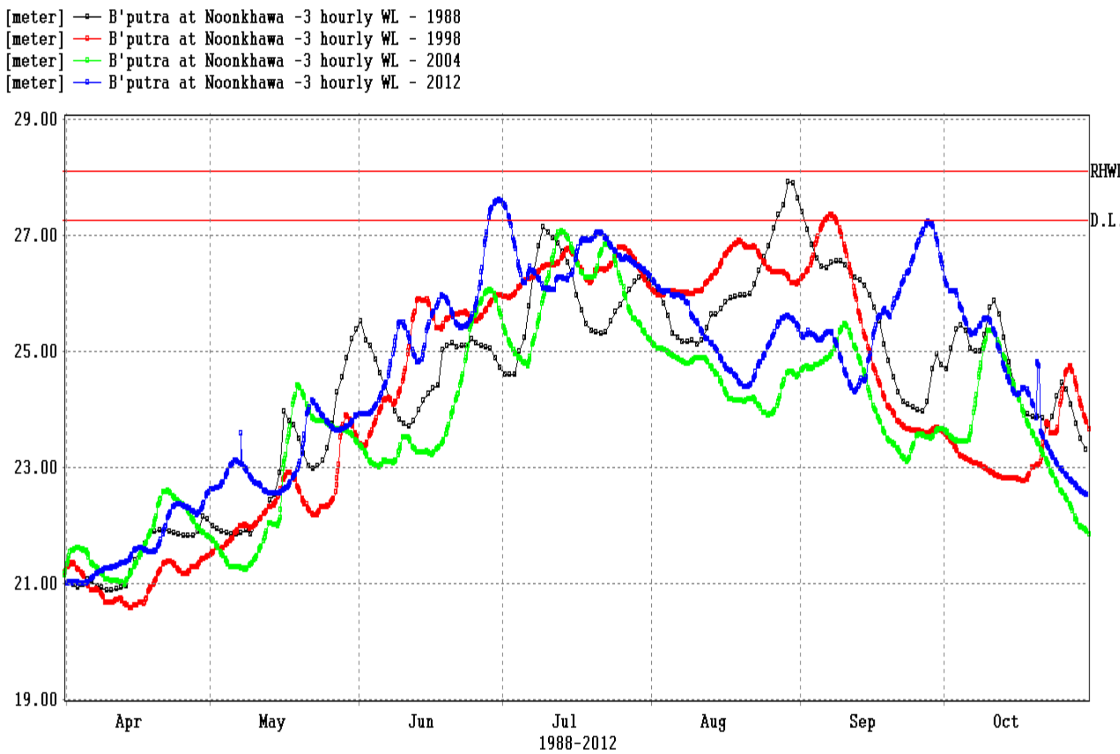


Figure 3.7 : Comparison of Hydrograph on Brahmaputra at Noonkhawa

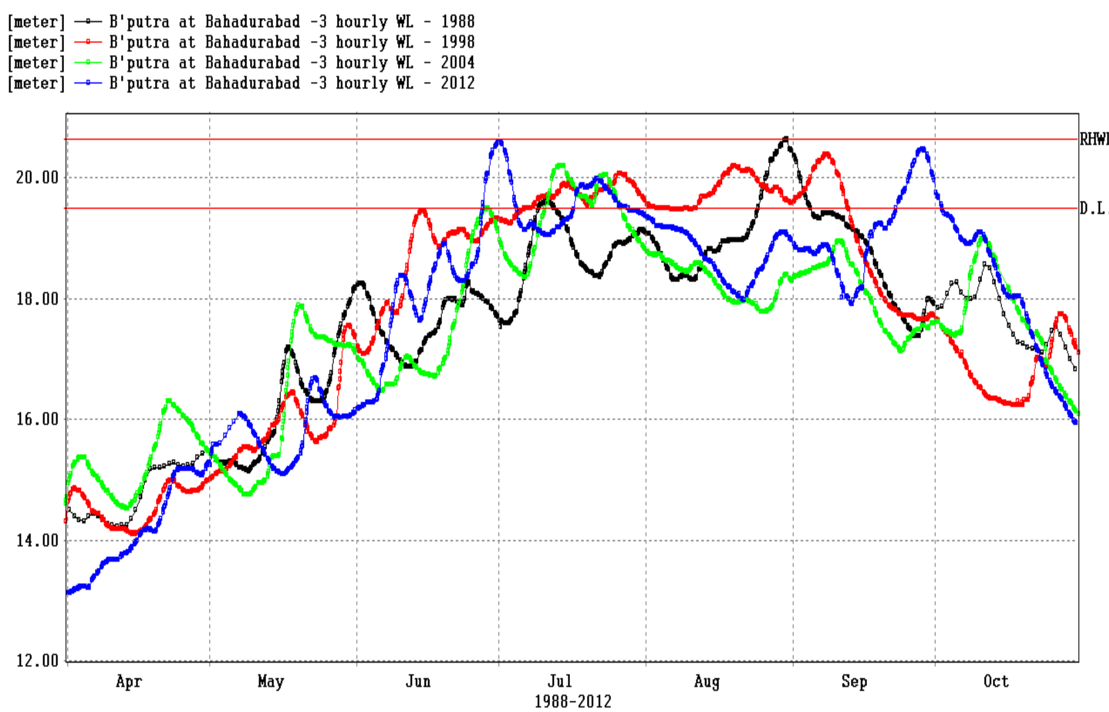


Figure 3.8 : Comparison of Hydrograph on Brahmaputra at Bahadurabad

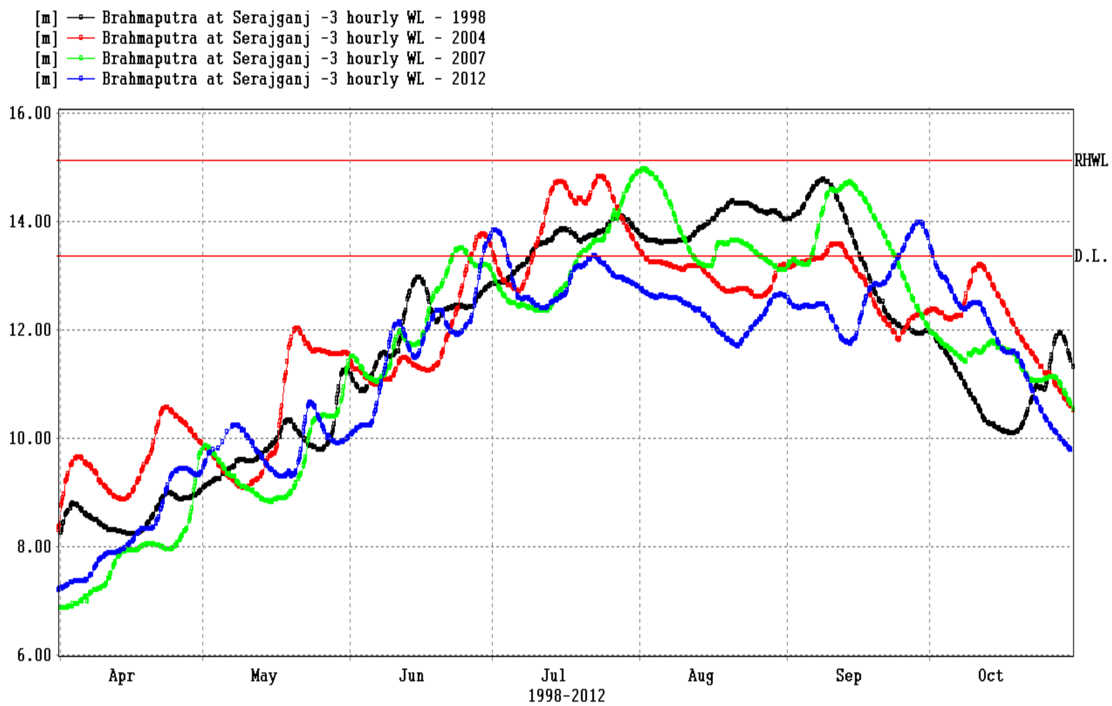


Figure 3.9 : Comparison of Hydrograph on Jamuna at Serajgonj

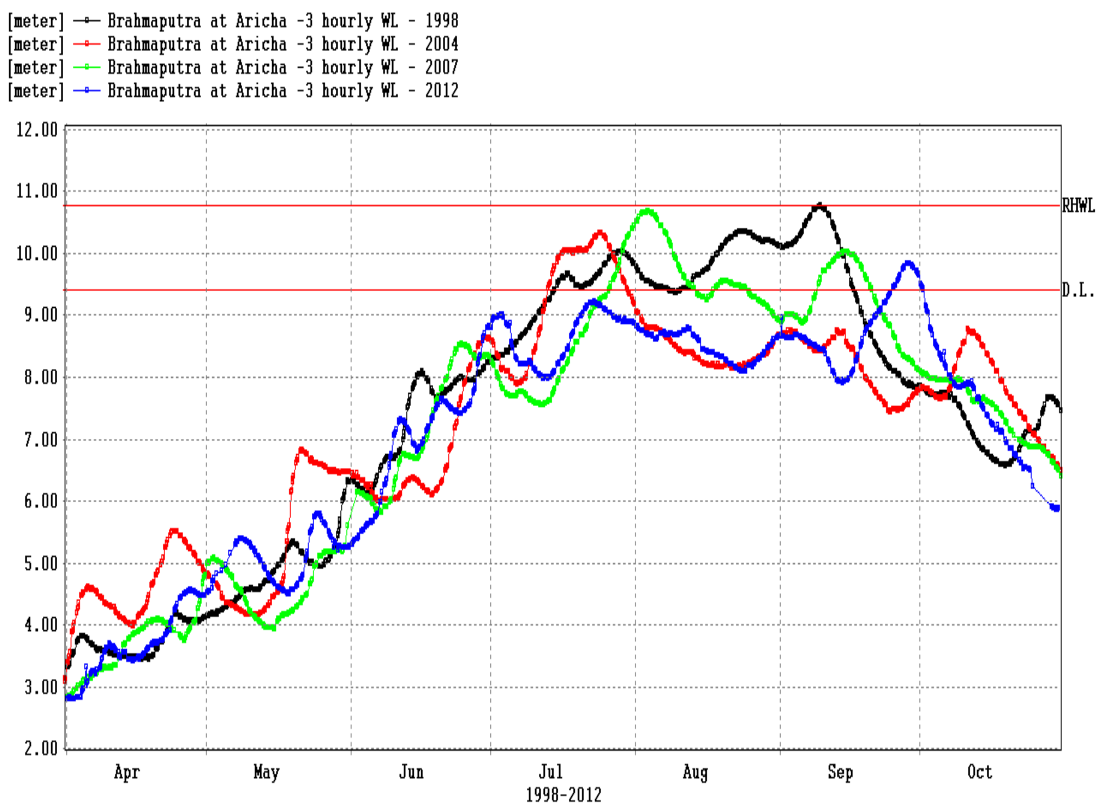


Figure 3.10 : Comparison of Hydrograph on Jamuna at Aricha

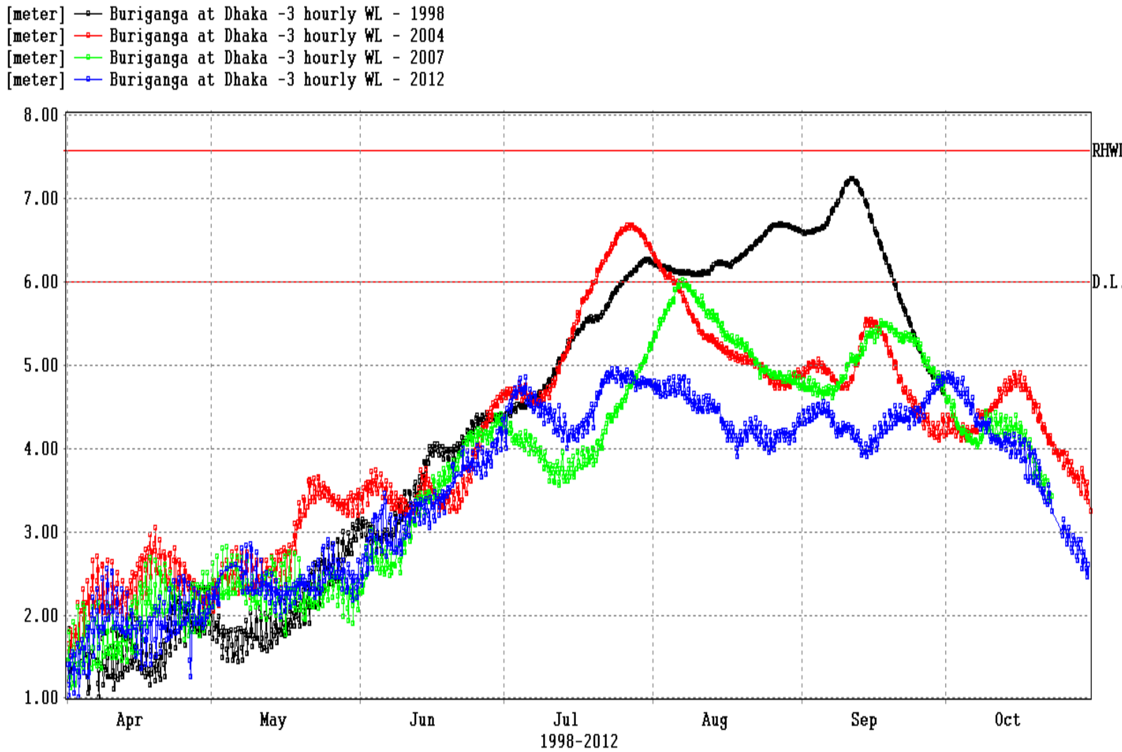


Figure 3.11 : Comparison of Hydrograph on Buriganga at Dhaka(Milbarak)

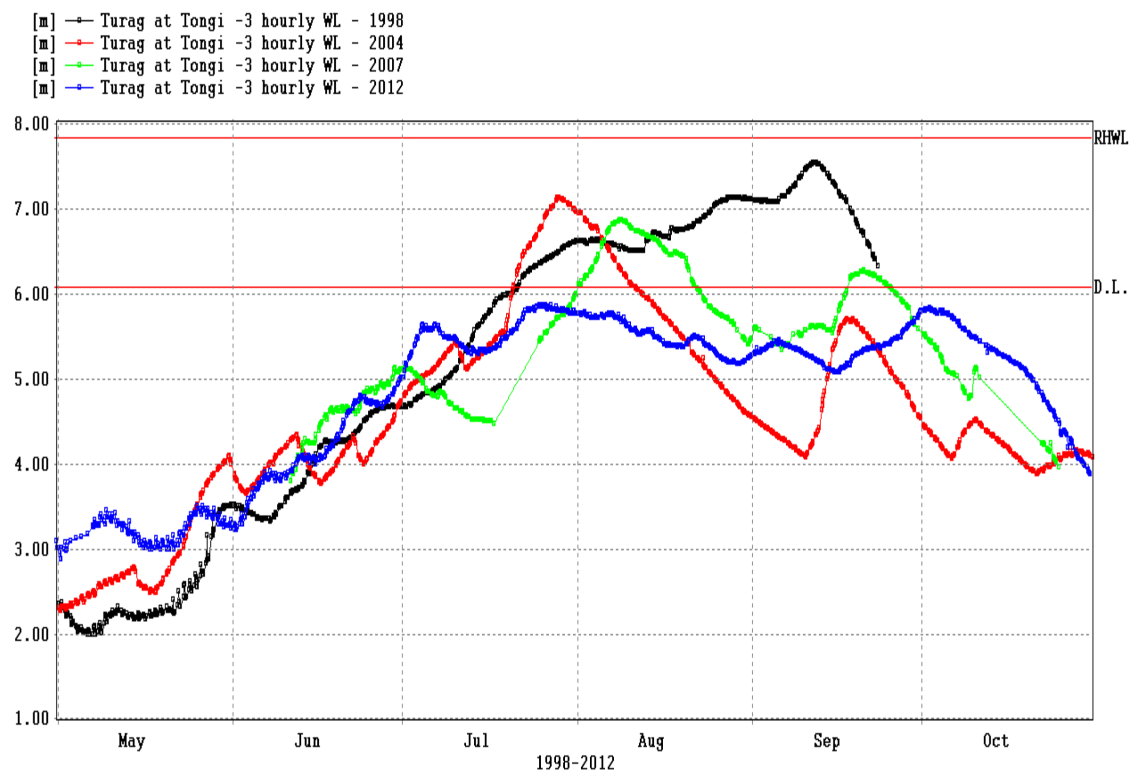


Figure 3.12 : Comparison of Hydrograph on Tongi Khal at Tongi

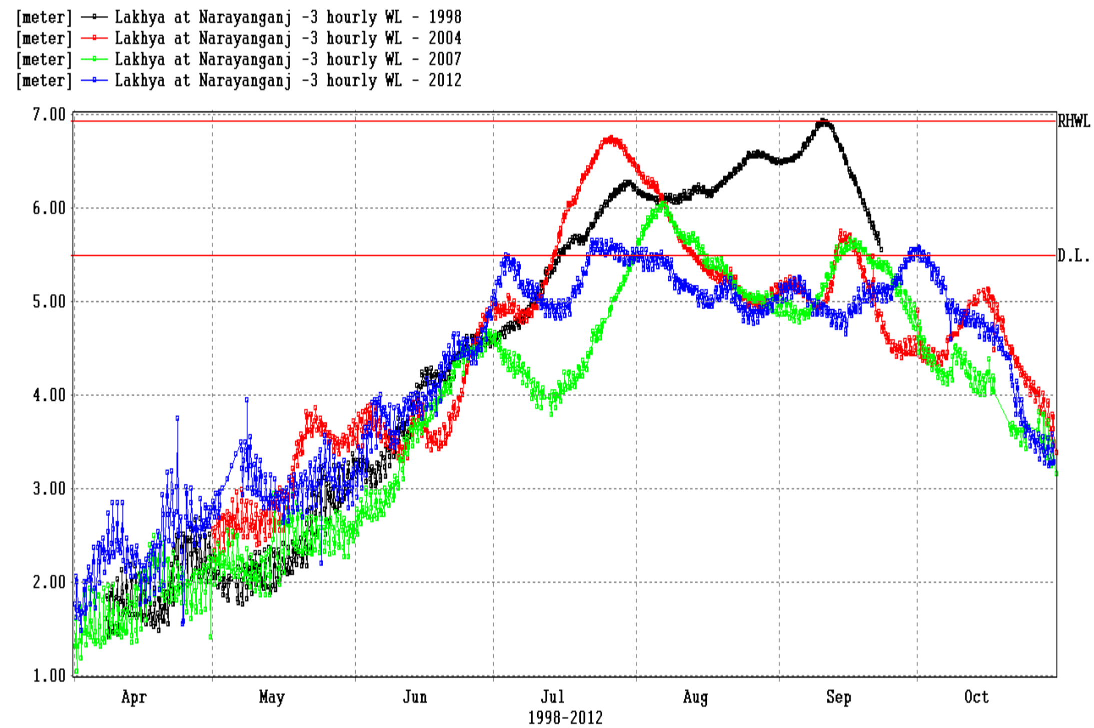


Figure 3.13 : Comparison of Hydrograph on Lakhya at Narayangonj

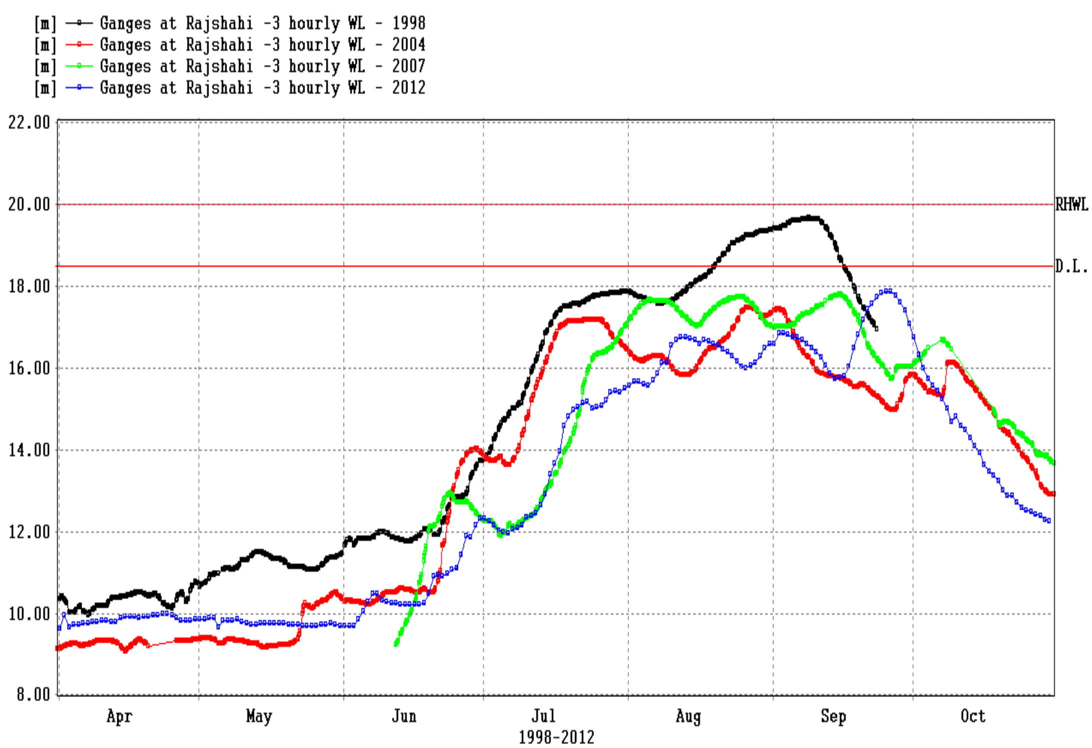


Figure 3.14 : Comparison of Hydrograph on Ganges at Rajshahi

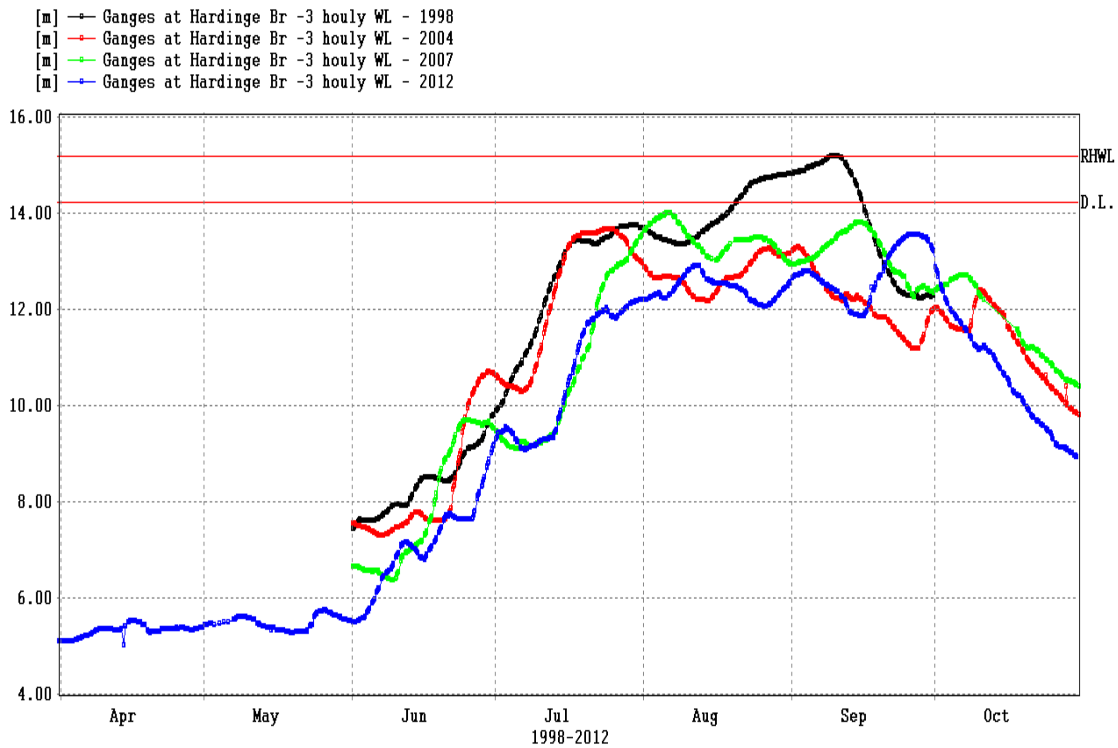


Figure 3.15 : Comparison of Hydrograph on Ganges at Hardinge Bridge

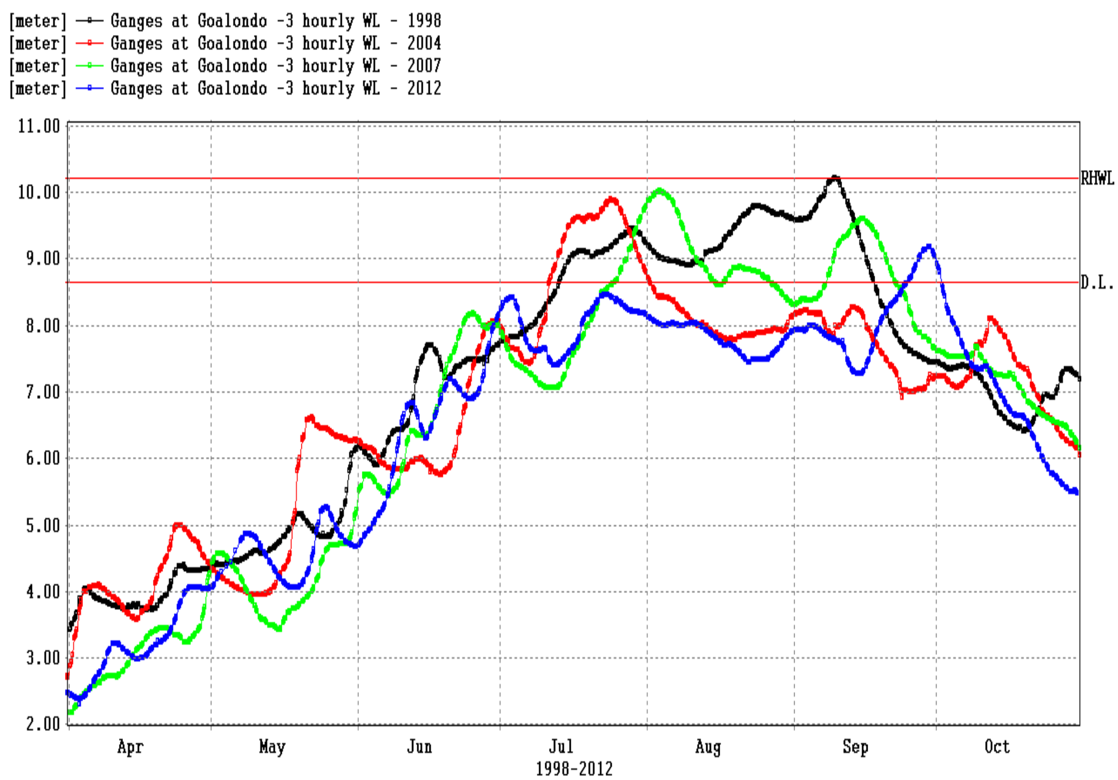


Figure 3.16 : Comparison of Hydrograph on Padma at Goalondo

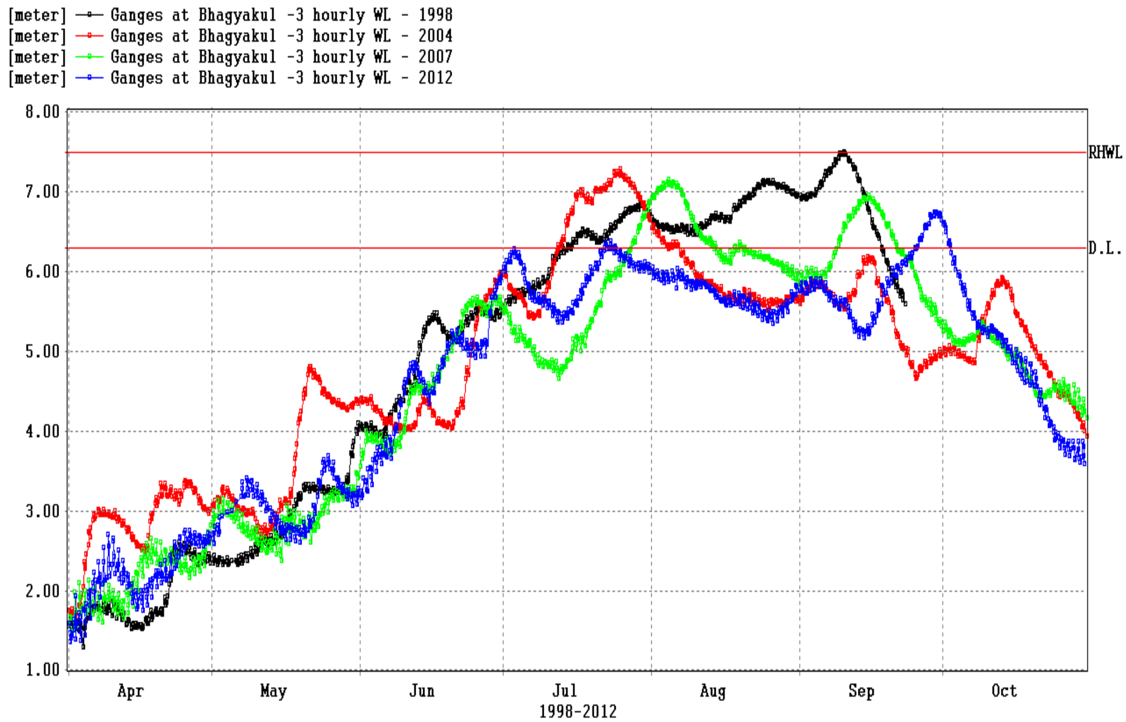


Figure 3.17 : Comparison of Hydrograph on Padma at Bhagyakul

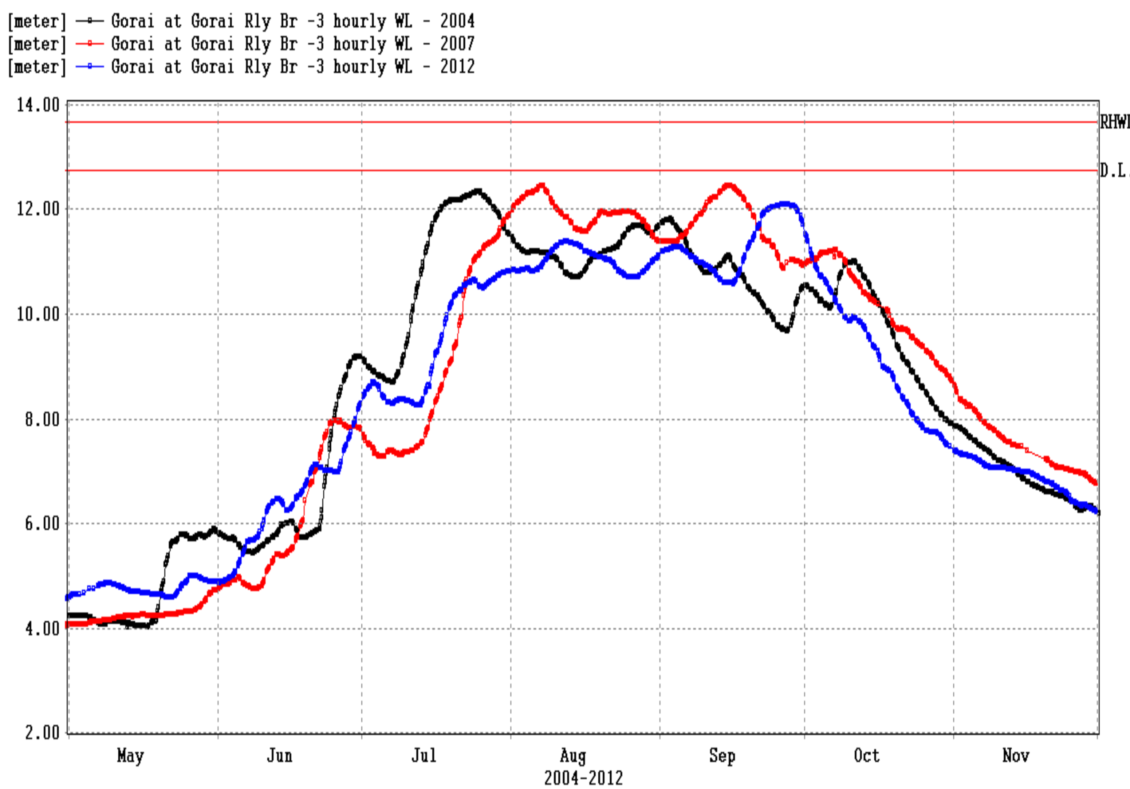


Figure 3.18 : Comparison of Hydrograph on Gorai at Gorai Railway Bridge

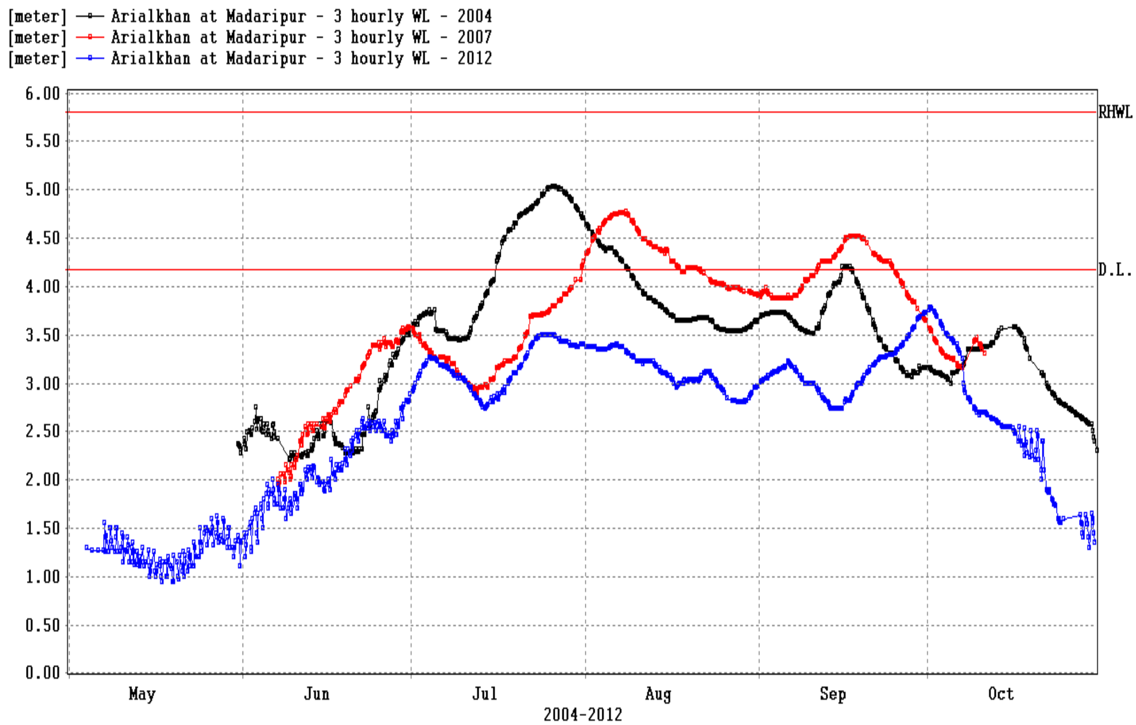


Figure 3.19 : Comparison of Hydrograph on Arialkhan at Madaripur

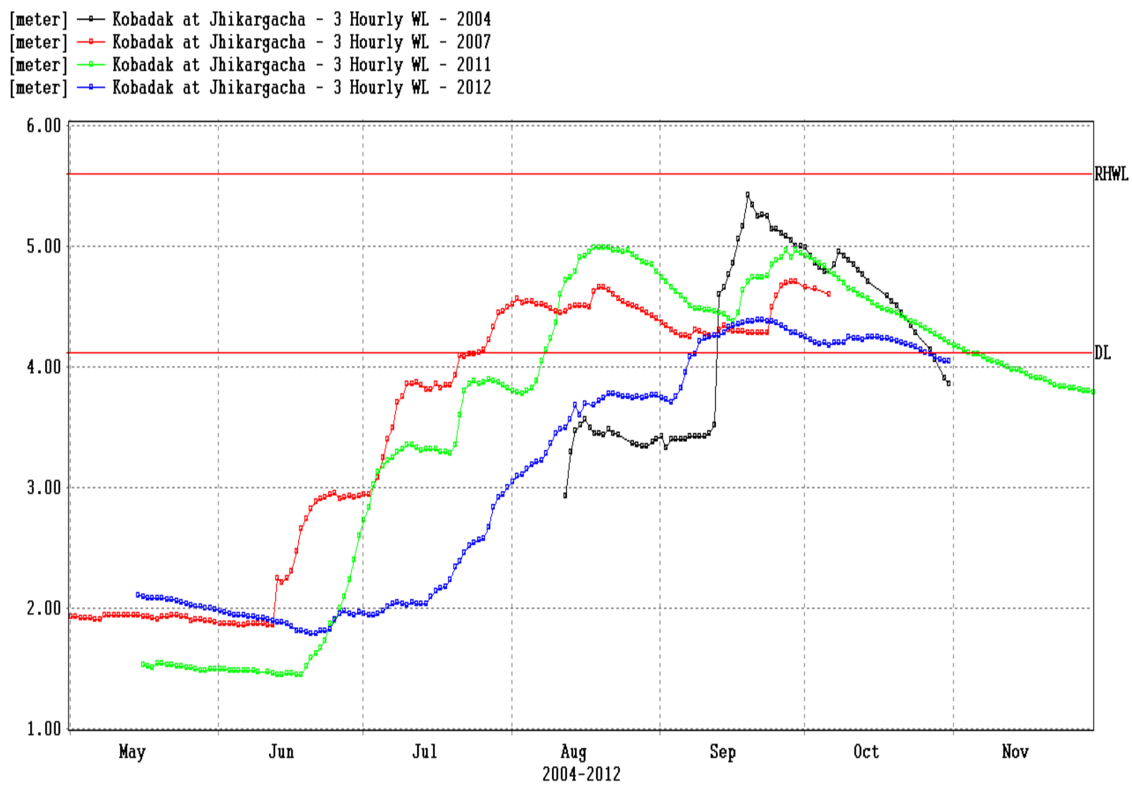


Figure 3.20 : Comparison of Hydrograph on Kobodak at Jhikorgacha

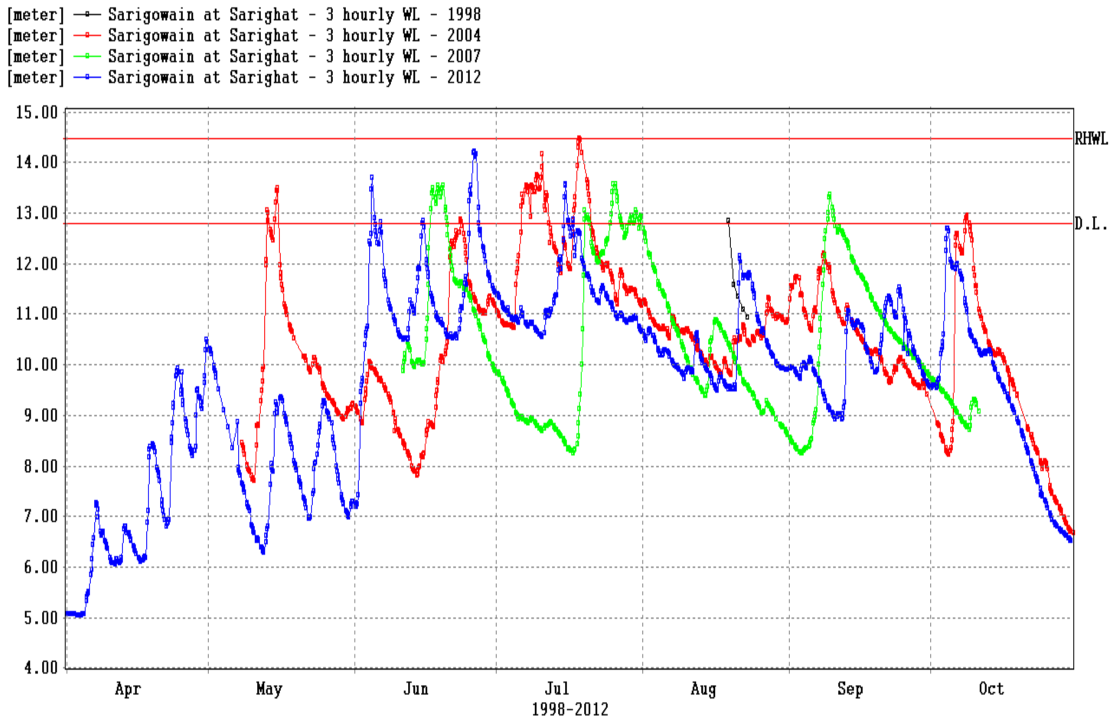


Figure 3.21 : Comparison of Hydrograph on Sarigoain at Sarighat

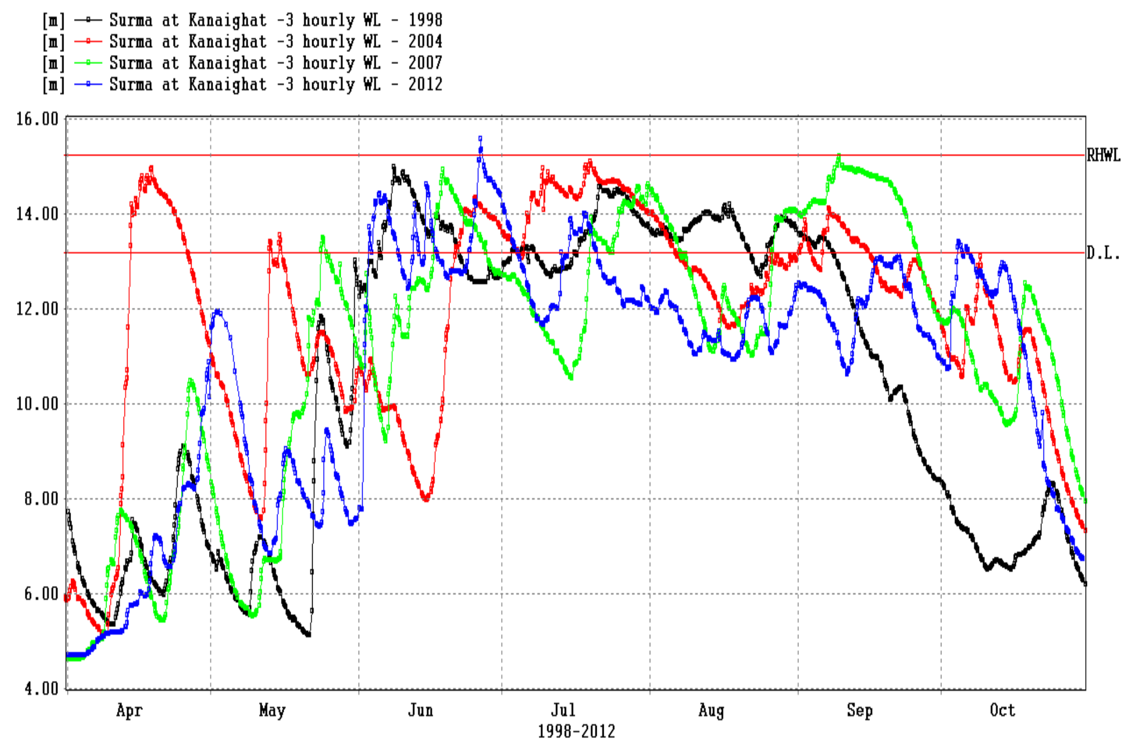


Figure 3.22 : Comparison of Hydrograph on Surma at Kanaighat

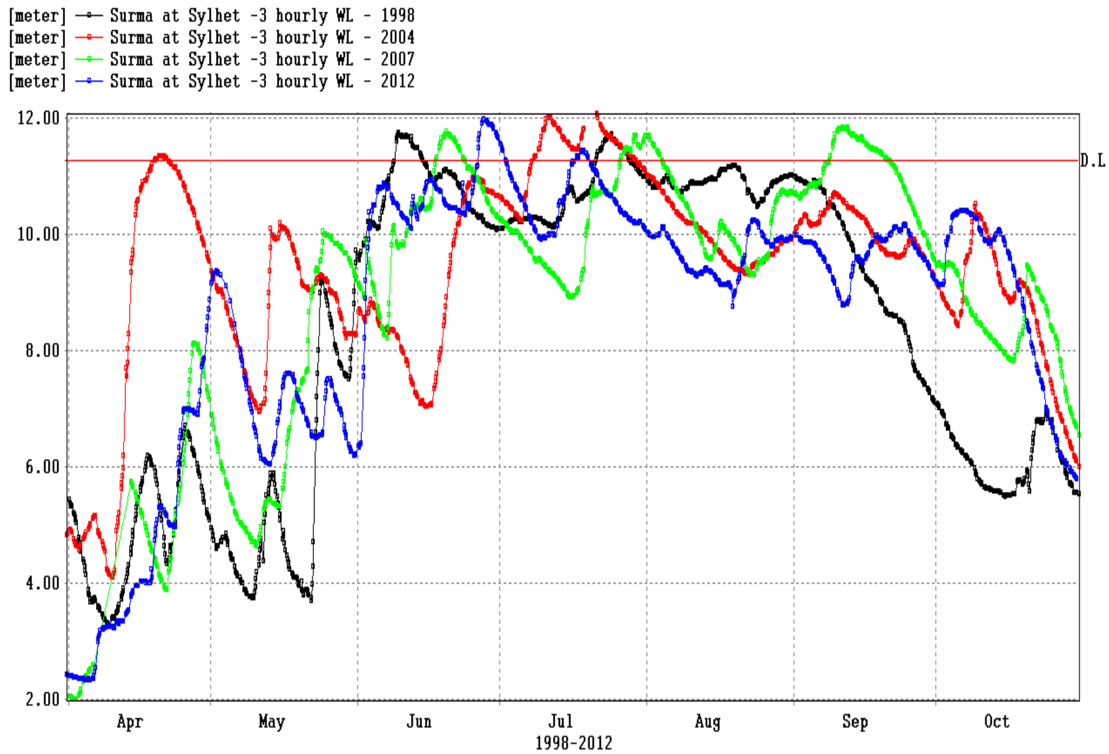


Figure 3.23 : Comparison of Hydrograph on Surma at Sylhet

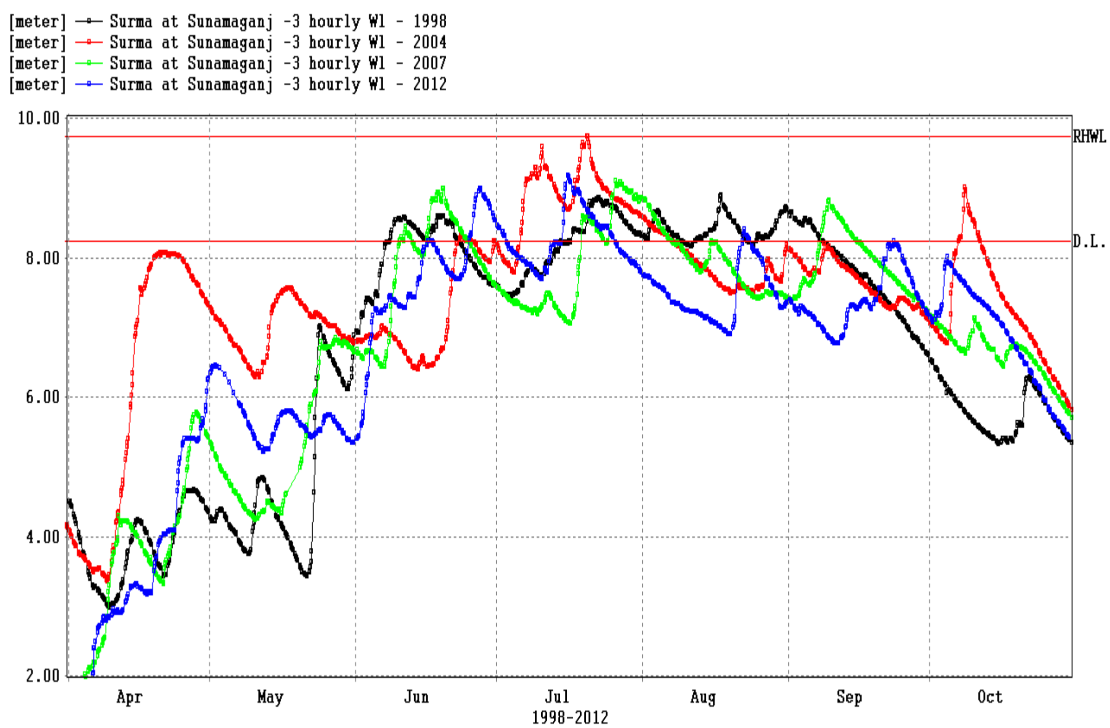


Figure 3.24 : Comparison of Hydrograph on Surma at Sunamgonj

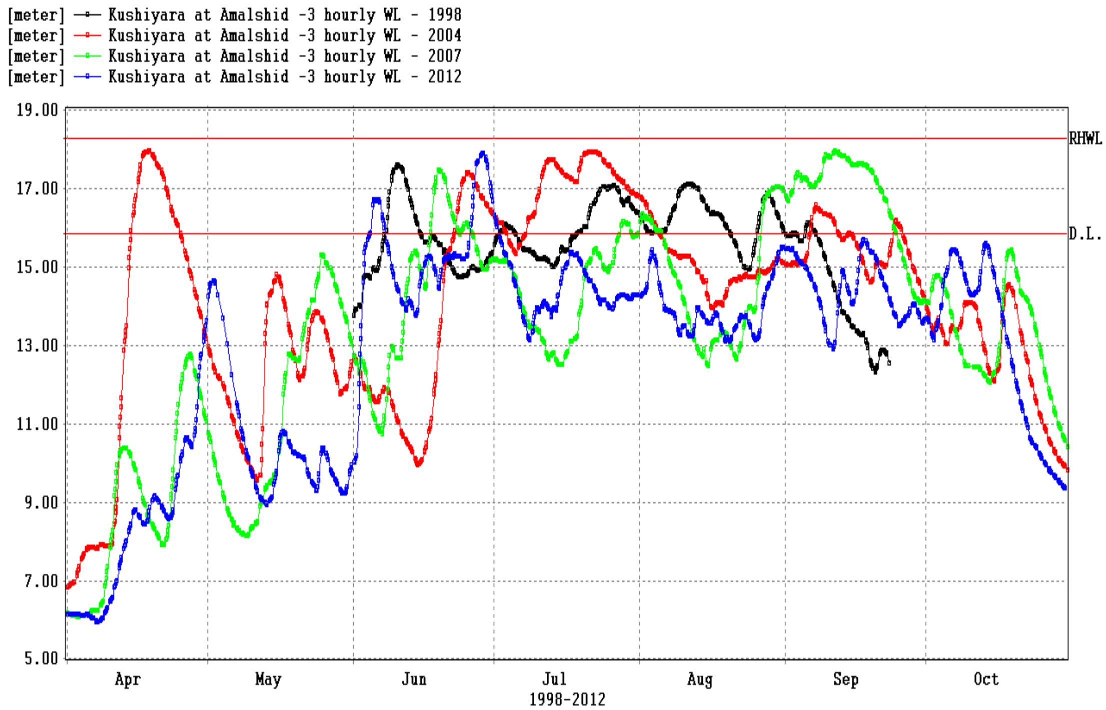


Figure 3.25 : Comparison of Hydrograph on Kushiyara at Amalshid

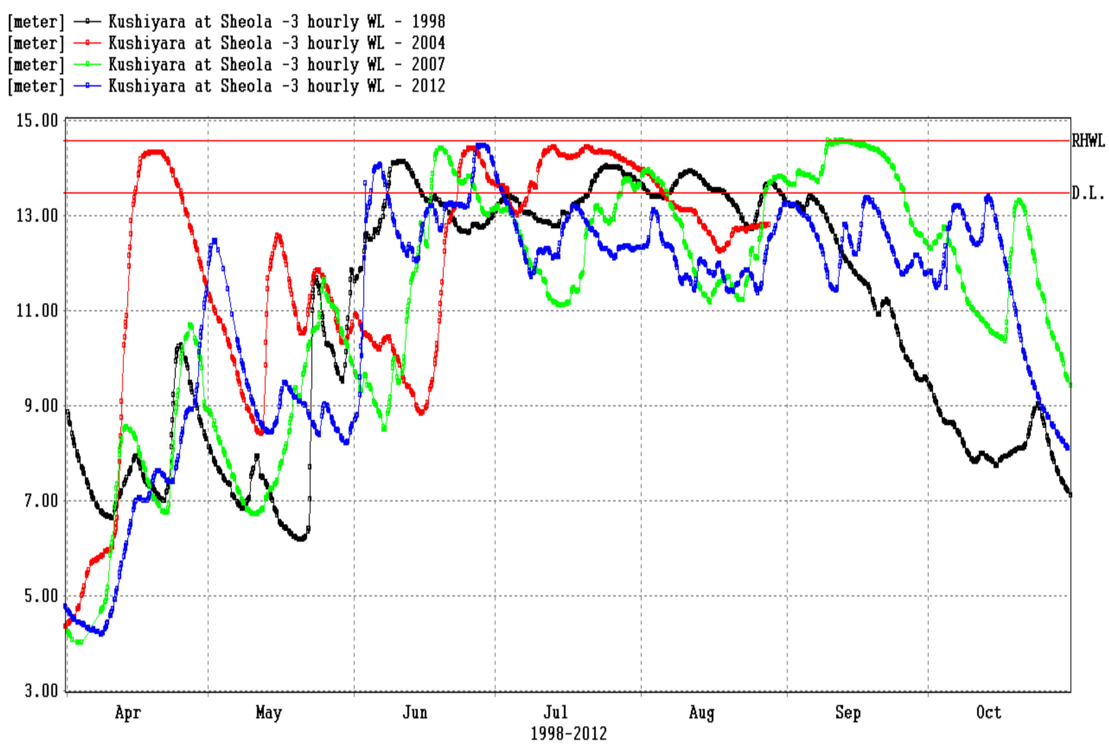


Figure 3.26 : Comparison of Hydrograph on Kushiyara at Sheola

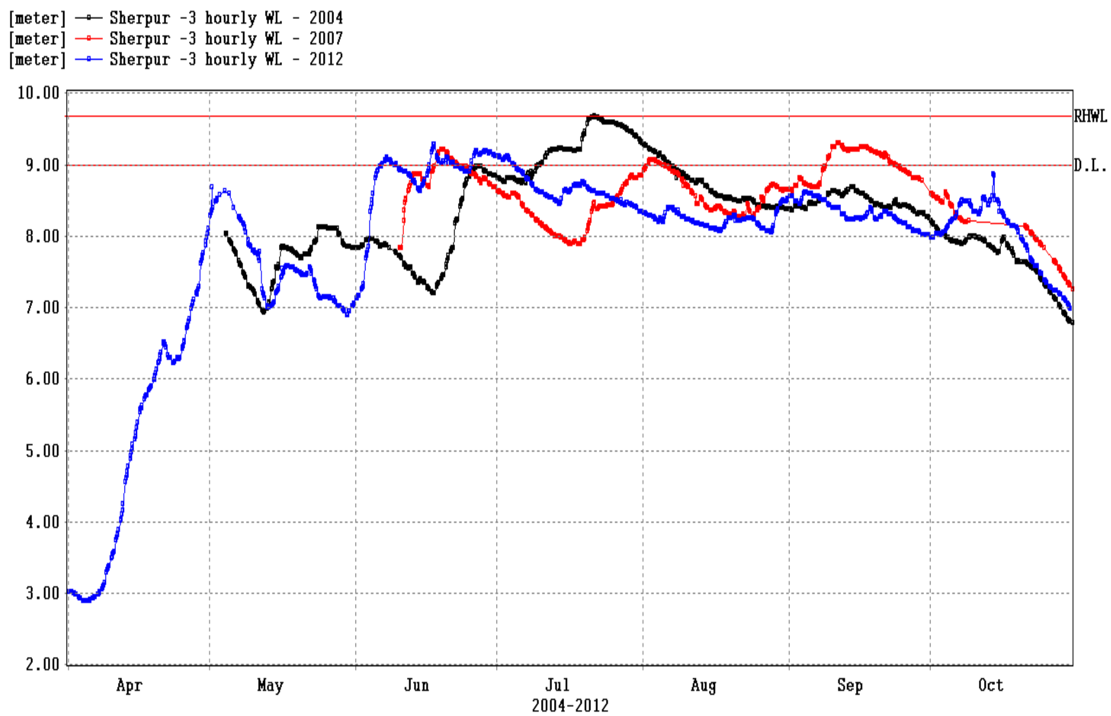


Figure 3.27 : Comparison of Hydrograph on Kushiyara at Sherpur

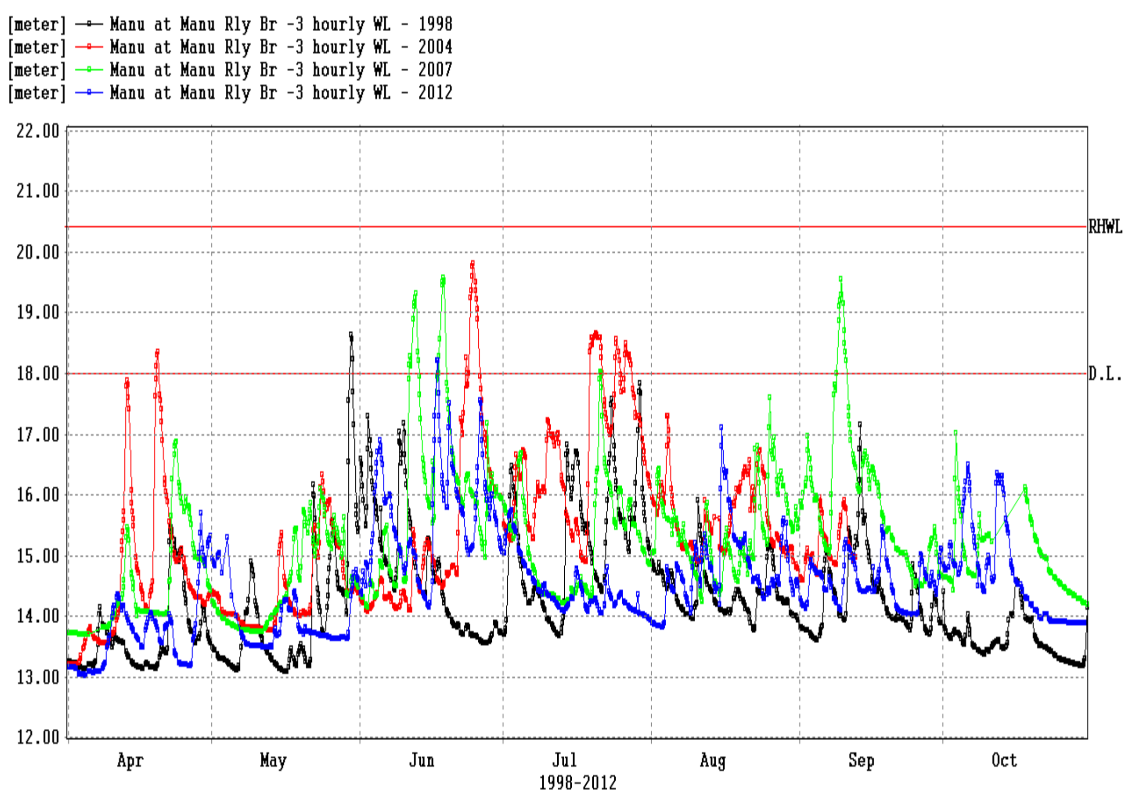


Figure 3.28 : Comparison of Hydrograph on Manu at Manu Rail Bridge

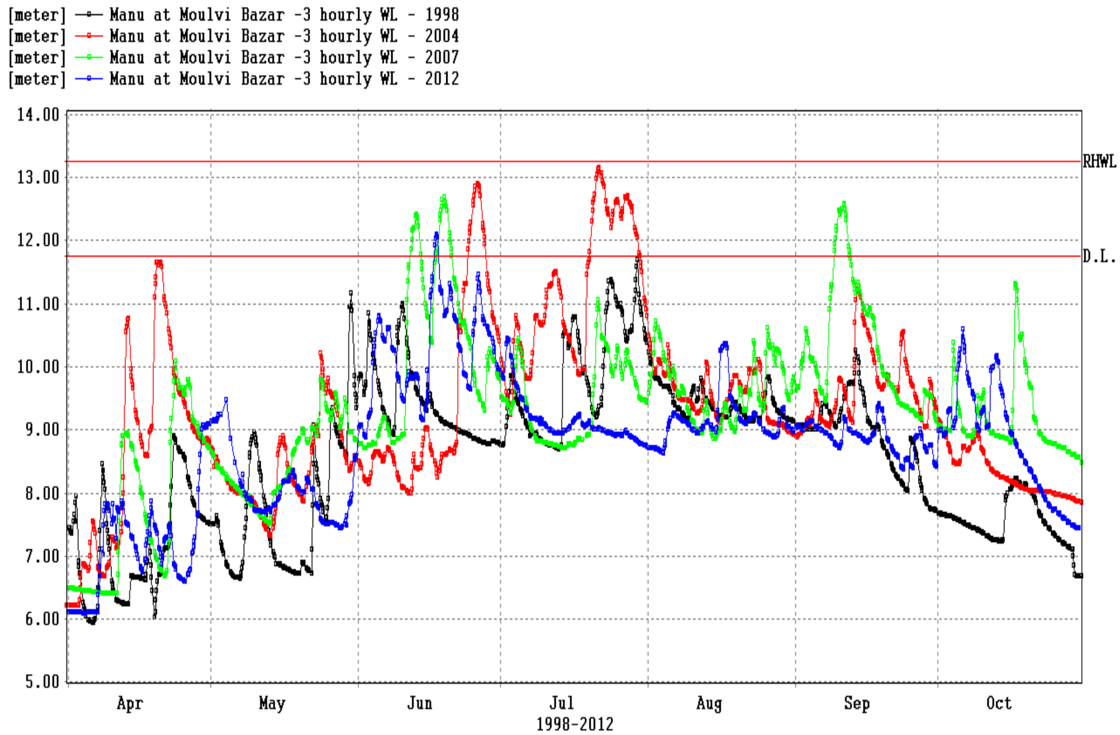


Figure 3.29 : Comparison of Hydrograph on Manu at Moulvibazar

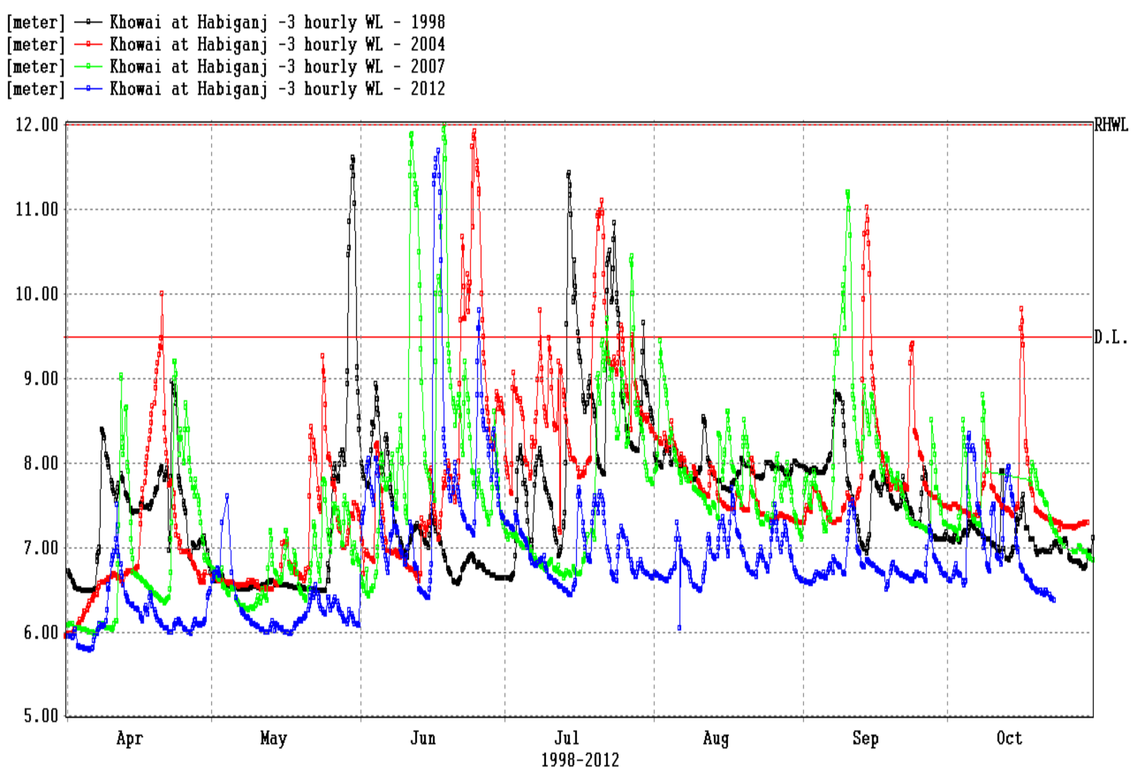


Figure 3.30 : Comparison of Hydrograph on Khowai at Habigonj

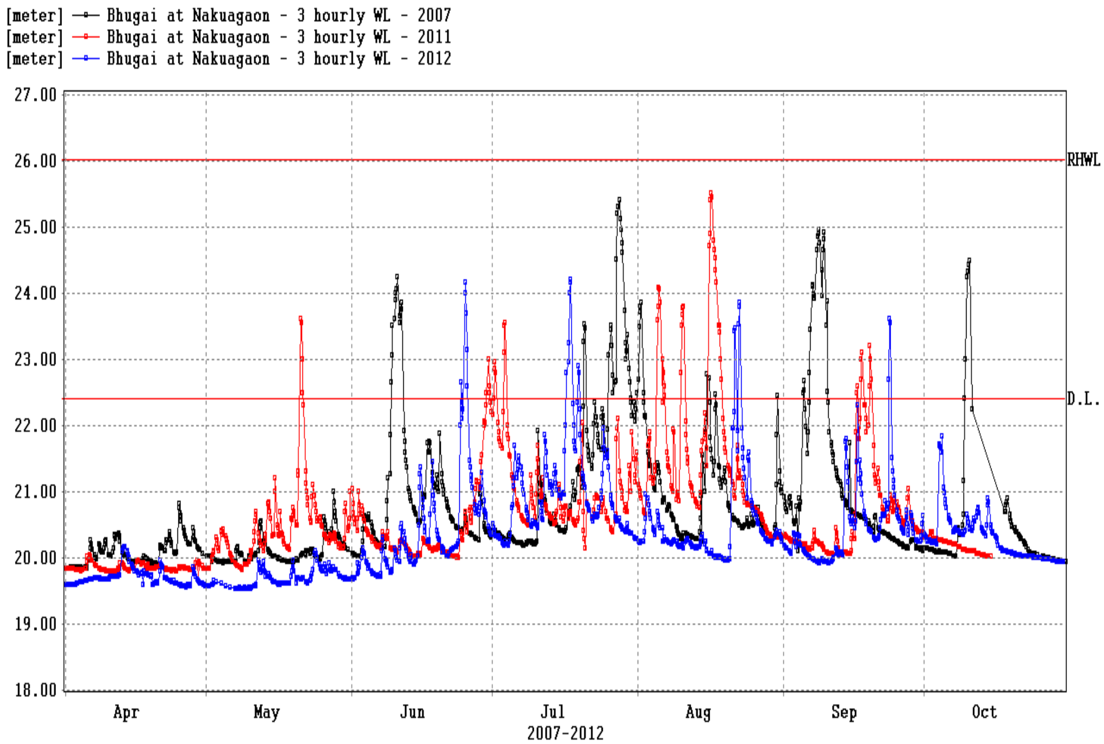


Figure 3.31 : Comparison of Hydrograph on Bhugai at Nokuagaon

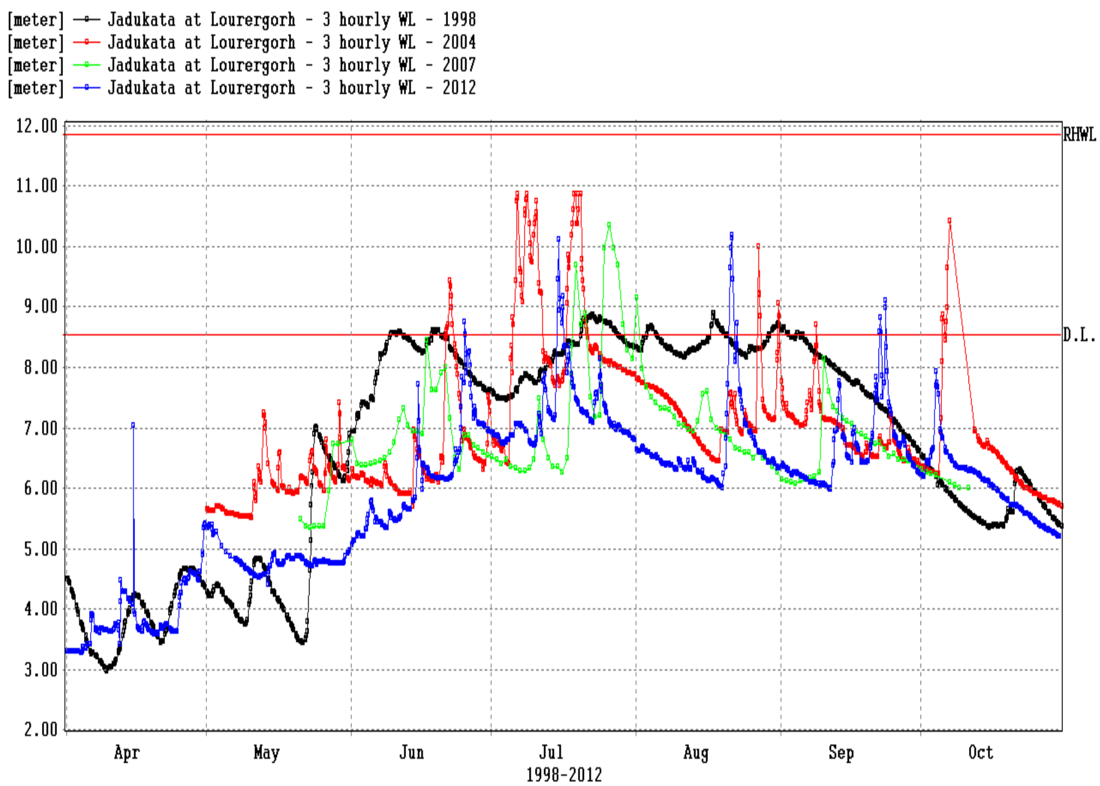


Figure 3.32 : Comparison of Hydrograph on Jadukata at Lorerghor

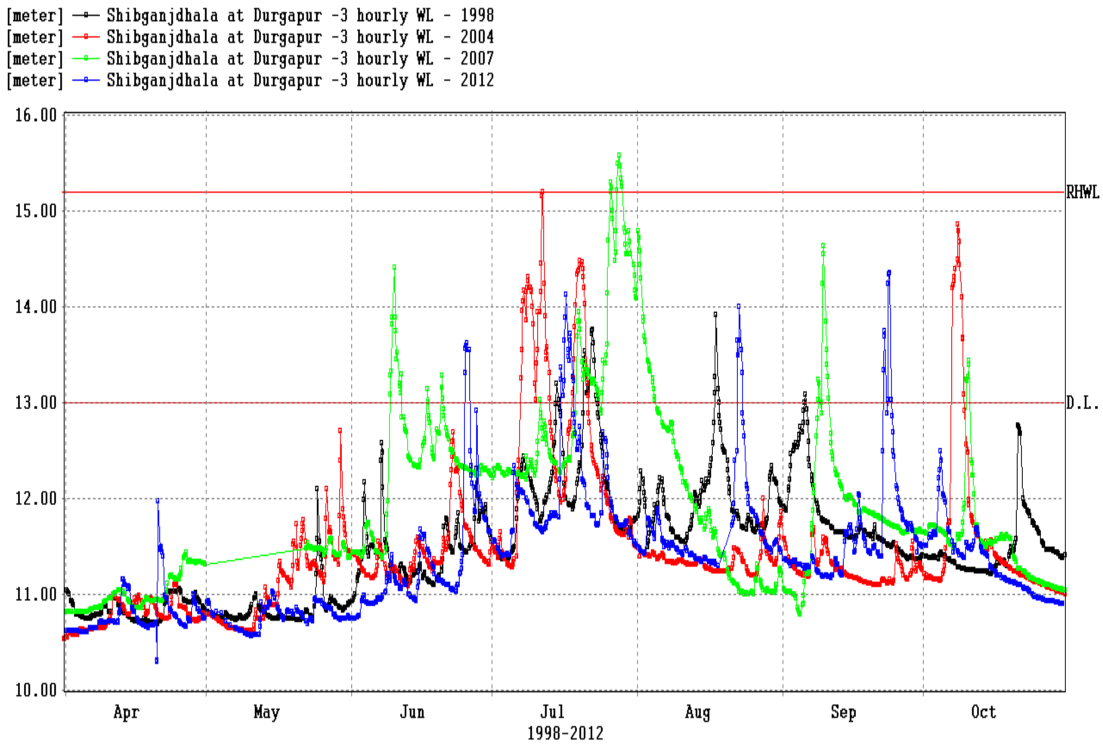


Figure 3.33 : Comparison of Hydrograph on Someswari at Durgapur

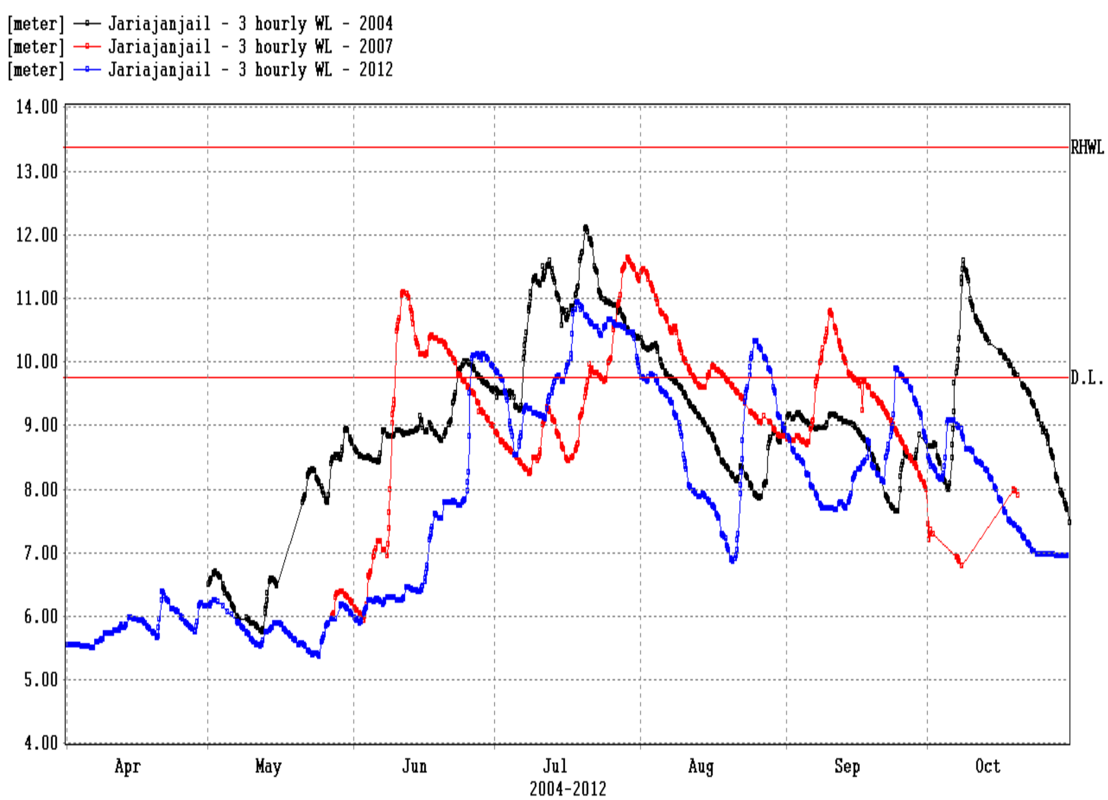


Figure 3.34 : Comparison of Hydrograph on Kangsha at Jariajanjail

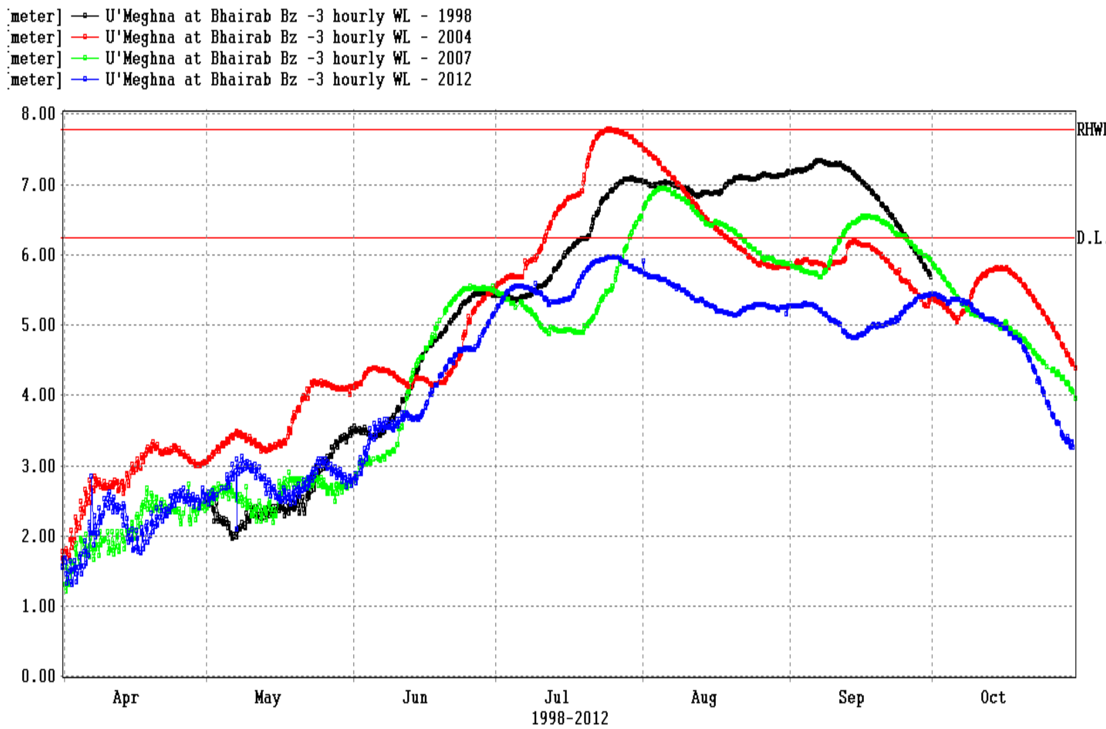


Figure 3.35 : Comparison of Hydrograph on Upper Meghna at Bhairab Bazar

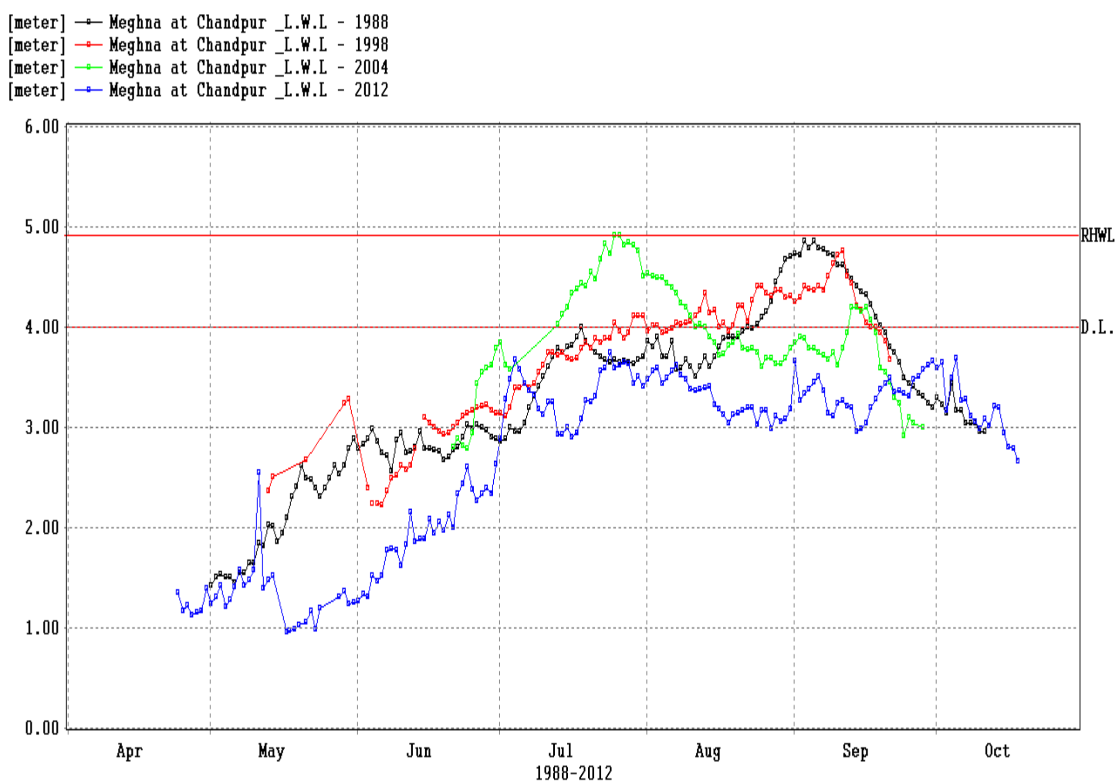


Figure 3.36 : Comparison of Hydrograph on Lower Meghna at Chandpur

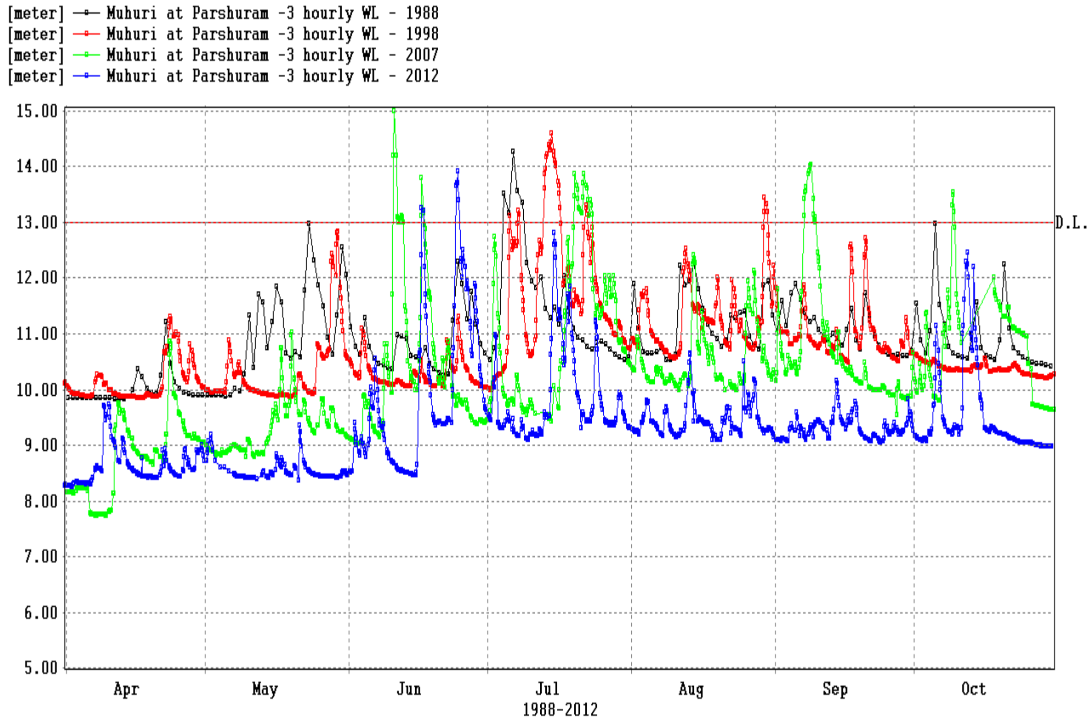


Figure 3.37 : Comparison of Hydrograph on Muhuri at Parshuram

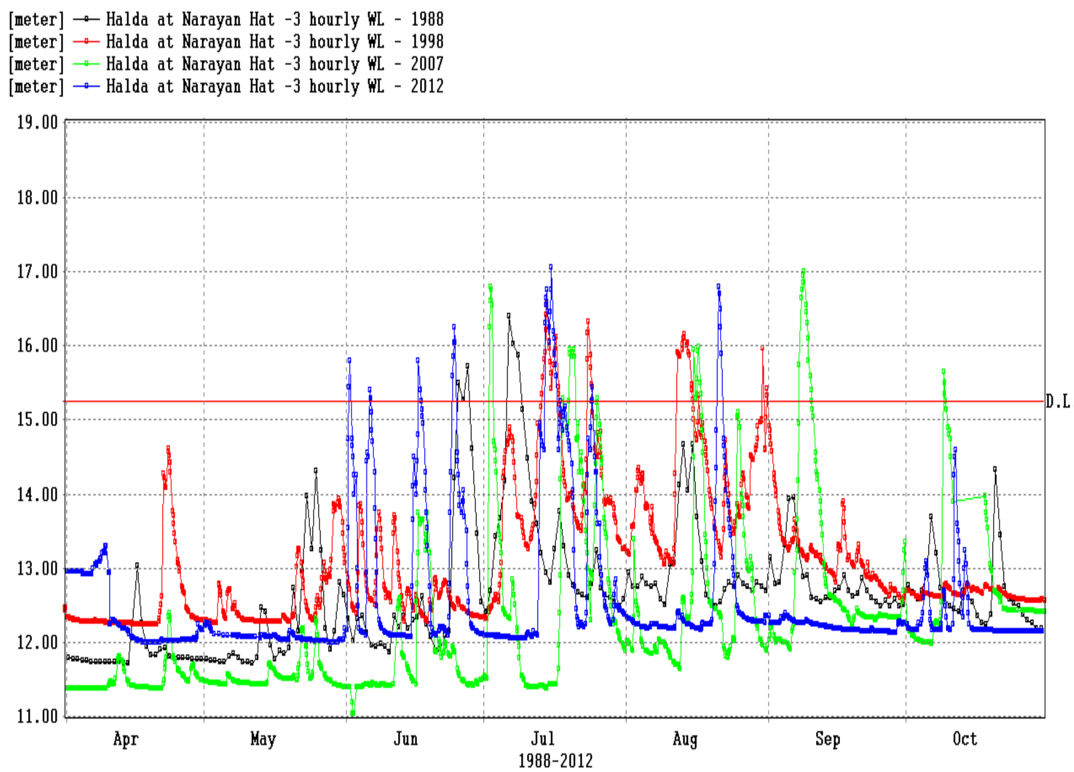


Figure 3.38 : Comparison of Hydrograph on Halda at Narayanhat

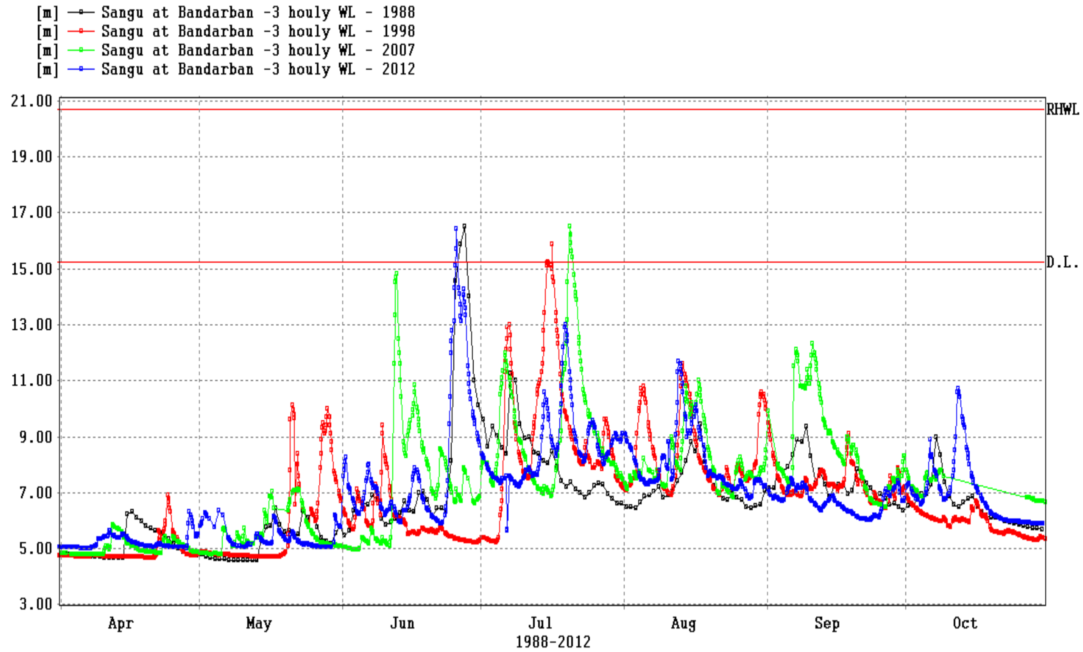


Figure 3.39 : Comparison of Hydrograph on Sangu at Bandarban

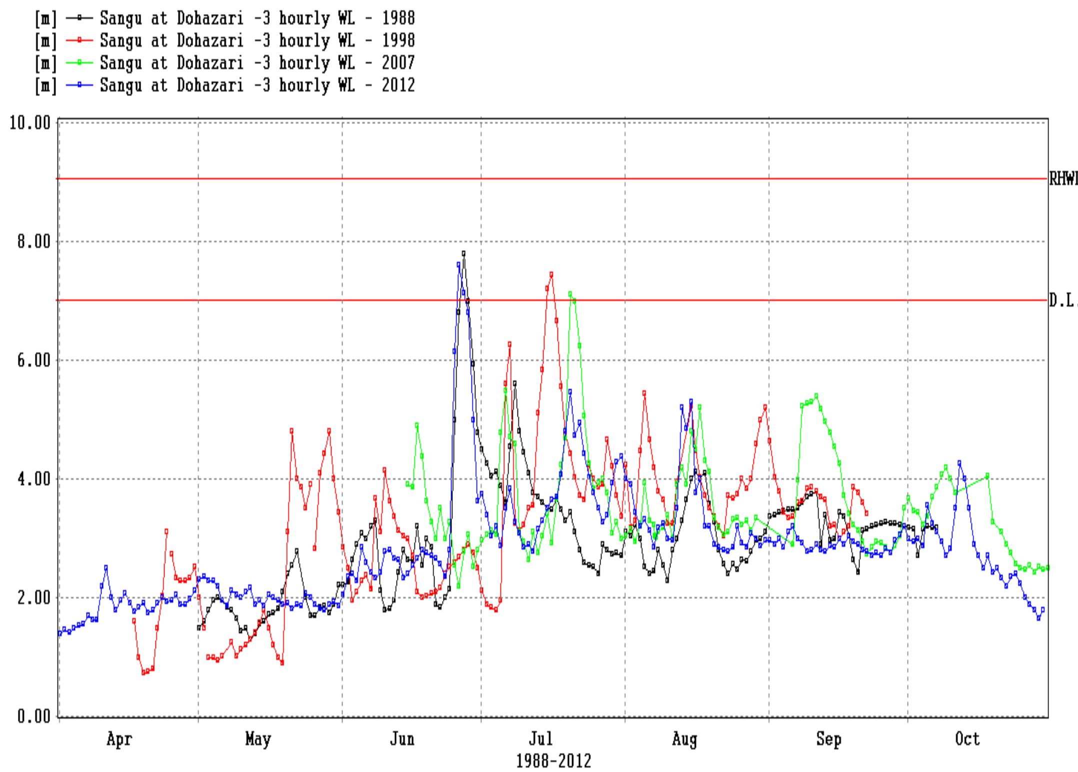


Figure 3.40 : Comparison of Hydrograph on Sangu at Dohazari

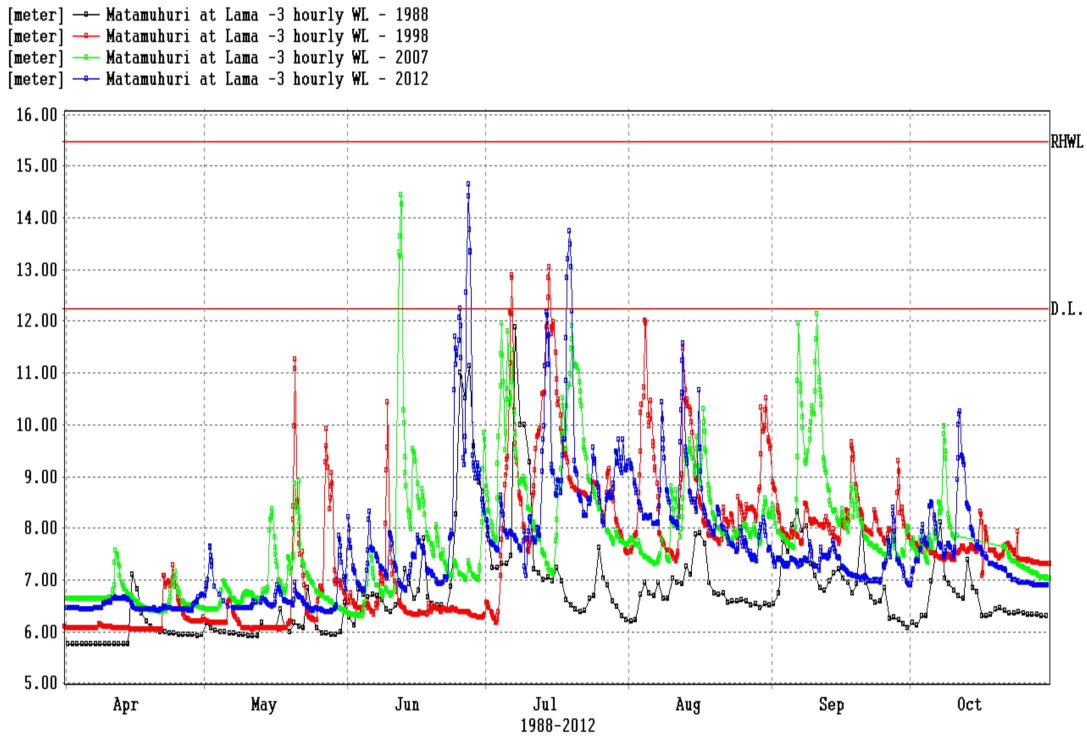


Figure 3.41 : Comparison of Hydrograph on Matamuhuri at Lama

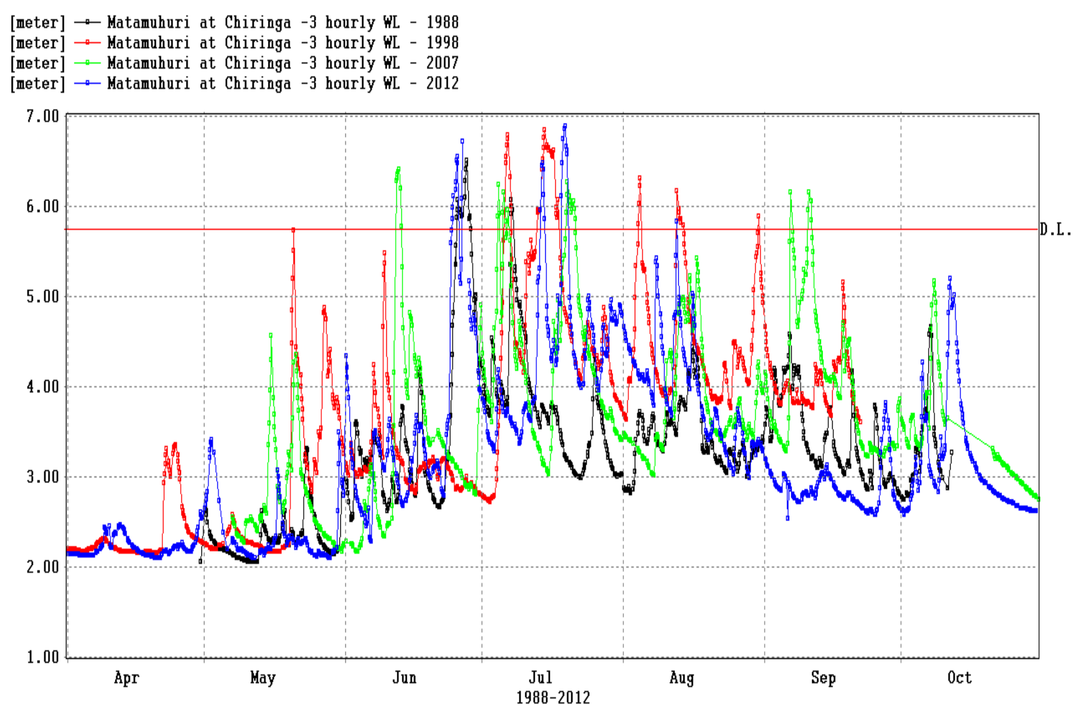


Figure 3.42 : Comparison of Hydrograph on Matamuhuri at Chiringa

CHAPTER 4: FORECAST EVALUATION, 2012

4.1 GENERAL

Flood Forecasting and Warning Centre (FFWC) of BWDB is mandated for preparation of flood forecasting, early warning and its dissemination in Bangladesh (BWDB Act-2000). Flood forecasting models of FFWC are developed on MIKE 11, one-dimensional modeling software used for the simulation of WLs and discharges in the river network and flood plains. Presently early warning on floods provides a lead time of 24, 48 and 72 hours. There are needs and expectations for increasing lead time forecast for cropping decisions, such as early harvesting, or to implement a contingency crop plan or protect infrastructure and preserve livelihoods. A research initiative has been started from July 2011 to increase lead time for deterministic flood forecast upto 5 days from existing 3-days and to extend the Flood Forecast to few selected BWDB projects with support from CDMP-II under Ministry of Food and Disaster Management (MoFDM) (from middle of 2012 renamed as Ministry of Disaster Management and Relief).

The Climate Forecast Applications in Bangladesh (CFAB) project was supported by USAID/OFDA to develop and evaluate three tier overlapping forecast system with improved lead time during monsoon season 2003 and 2004, which showed a success in forecasting the discharges at Hardinge Bridge station of Ganges and Bahadurabad stations of Brahmaputra rivers of Bangladesh. From March 2006 – June 2009, CARE-Bangladesh and United States Agency for International Development (USAID), Dhaka supported the program with an objective to technology transfer and capacity building for sustainable end-to-end generation and application through pilot projects at selected sites.

The project implemented with the active participation of key stakeholders in Bangladesh through a Steering Committee process. Membership in the CFAB Steering Committee includes the Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Department of Agriculture Extension (DAE), Department of Disaster Management (DDM), Center for Environmental and Geographic Information Services (CEGIS), Institute of Water Modeling (IWM), and CARE Bangladesh. The Steering Committee meets periodically to review, monitor and guide the implementation of CFAB in Bangladesh. Medium range 10-day lead time probability based flood forecast to a limited number of places (only 18 points) on experimental basis has been initiated under the project. After the termination of the support from the USAID-CARE, this has been continued with technical support from the RIMES. Another initiative has been started from July 2012 to expand the number of points for medium range 10-day lead time probability based flood forecast to increase the area coverage along with long range seasonal flood forecast on experimental basis with support from CARE and RIMES.

4.2 EVALUATION CRITERIA OF FORECAST PERFORMANCE

Two statistical criteria considered for the performance evaluation of the model are as follows:

- Mean Absolute Error, MAE
- Co-efficient of Determination, r^2

4.2.1 MEAN ABSOLUTE ERROR (MAE)

MAE is the mean of the absolute difference between *Observed* and *Forecast* levels as shown in the following equation:

$$MAE = \frac{\sum_{i=1}^{n} |x_i - y_i|}{n}$$

Where,

$x_1, x_2 \ldots\ldots x_n$ are *Observed* water levels
$y_1, y_2 \ldots\ldots y_n$ are *Forecast* water levels
n is the number of *Observed/Forecast* levels

4.2.2 CO-EFFICIENT OF DETERMINATION, R2

r^2 is the *Co-efficient of Determination* for the correlation of *Observed* and *Forecast* water levels and is given by the relation as show in the equation below:

$$r^2 = \frac{\left[\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})\right]^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}$$

Where,

$x_1, x_2 \ldots\ldots x_n$ are *Observed* water levels

$\bar{x}$ is the average of *Observed* water levels

$y_1, y_2 \ldots\ldots y_n$ are *Forecast* water levels

$\bar{y}$ is the average of *Forecast* water levels

n is the number of *Observed/Forecast* levels

4.3 PRE-DEFINED SCALES TO EVALUATE FORECAST PERFORMANCE

The forecast performances for the monsoon-2012 have been evaluated from the statistical components r^2 (*Co-efficient of Determination*) and *MAE* (*Mean Absolute Error*). Values of the above two components in their ideal case are generally assumed to be in the order of

$MAE = 0$

$r^2 = 1$

Utilizing above two indicators, 5 category scales have been used to describe forecast performances. Stations having a minimum value of 0.9 for r^2 and a maximum value of 15 centimeter for *MAE* have been considered as "*Good*" performance. Table 4.1 presents the definition of scales used in the evaluation:

Table 4. 1 : Scales used for performance evaluation

Sl. No.	Scale	Value
1	*Good*	*MAE* <= 0.15 meter & r^2 >= 0.9
2	*Average*	*MAE* <= 0.2 meter & >0.15 meter and r^2 >= 0.7 & <0.9
3	*Not satisfactory*	*MAE* <= 0.3 meter & >0.2 meter and r^2 >= 0.4 & <0.7
4	*Poor*	*MAE* <= 0.4 meter& >0.3 meter and r^2 >= 0.3 & <0.4
5	*Very Poor*	*MAE* > 0.4 meter or r^2 < 0.3

Simulations were made for maximum 72 hours in the forecast period and forecasts were saved in the database at 24-hour and 48-hour and 72-hour intervals. Usually, the forecast quality gradually deteriorated with higher forecast intervals from the time of forecast. As lead time increases the forecast accuracy decreases. This means that forecasts are the best at 24-hour interval followed by 48-hour interval and then 72-hour interval. Figures from 4.1 to 4.3 are shown the comparison of observed and forecasted WL for 24, 48 and 72 hours. Result of the statistical analysis and performance on the basis of the aforesaid scale are presented in Table 4.2, Table 4.3 and Table 4.4.

4.4 FORECAST STATISTICS AND MODEL PERFORMANCE, 2012

4.4.1 DETERMINISTIC FORECAST PERFORMANCE

For deterministic forecast, simulations were made for maximum 72 hrs. The forecast quality gradually deteriorated where forecast intervals were moved further away from the time of forecast. Usually as lead time increases the accuracy (variation of forecast & observe value) decreases. This means that forecasts were the best at 24-hour interval (i.e. 24 hrs/1-day lead time) followed by 48-hrs interval and then 72-hrs(3-days). Total 31 stations located within the model area (including some boundary stations) are evaluated. The forecast statistics along with their performance are provided in Tables 4.2 to 4.4 and in Figures 4.1 to 4.3. From the tables it may be seen that the forecast performance was 92% (Mean Absolute Error 8%), 85% (MAE 15%) and 79% (MEA 21%) accurate for 24hrs, 48hrs and 72 hrs respectively for the monsoon of 2012.

Table 4. 2 : Statistics for 24- hour forecast performance

Sl. No.	Station	MAE (m)	r2	Performance
1	Aricha	0.06	0.99	Good
2	Bahadurabad	0.07	0.97	Good
3	Bhagyakul	0.05	0.99	Good
4	Bhairabbazar	0.04	0.99	Good
5	Bhusirbandar	0.37	0.70	Not satisfactory
6	Bogra	0.18	0.90	Good
7	Chakrahimpur	0.18	0.83	Average
8	Chilmari	0.09	0.94	Good
9	Demra	0.06	0.98	Good
10	Dhaka	0.06	0.96	Good
11	Goalundo	0.05	0.99	Good
12	Gorai-RB	0.06	0.98	Good
13	Hardinge-BR	0.07	0.98	Good
14	Jagir	0.06	0.54	Average
15	Jamalpur	0.11	0.97	Good
16	Kamarkhali	0.06	0.97	Good
17	Kaunia	0.11	0.82	Average
18	Mirpur	0.04	0.98	Good
19	Moulvibazar	0.23	0.75	Not satisfactory
20	Mymensingh	0.10	0.98	Good
21	Mohadevpur	0.31	0.86	Poor
22	Naogaon	0.25	0.96	Poor
23	Narayangonj	0.07	0.96	Good
24	Nayarhat	0.07	0.93	Good
25	Rajshahi	0.10	0.97	Good
26	Serajgonj	0.04	0.98	Good
27	Sheola	0.20	0.88	Average
28	Sunamgonj	0.10	0.93	Good
29	Sylhet	0.12	0.90	Good
30	Taraghat	0.10	0.92	Good
31	Tongi	0.04	0.99	Good

Table 4. 3: Statistics for 48- hour forecast performance

Sl. No.	Station	MAE (m)	r2	Performance
1	Aricha	0.08	0.98	Good
2	Bahadurabad	0.17	0.90	Good
3	Bhagyakul	0.07	0.98	Good
4	Bhairabbazar	0.07	0.98	Good
5	Bhusirbandar	0.66	0.52	Very Poor
6	Bogra	0.35	0.74	Average
7	Chakrahimpur	0.32	0.76	Average
8	Chilmari	0.21	0.86	Good
9	Demra	0.10	0.95	Good
10	Dhaka	0.10	0.92	Good
11	Goalondo	0.08	0.98	Good
12	Gorai-RB	0.11	0.98	Good
13	Hardinge-BR	0.12	0.98	Good
14	Jagir	0.11	0.51	Average
15	Jamalpur	0.18	0.95	Good
16	Kamarkhali	0.10	0.97	Good
17	Kaunia	0.23	0.47	Average
18	Mirpur	0.08	0.96	Good
19	Moulvibazar	0.37	0.49	Poor
20	Mymensingh	0.19	0.95	Average
21	Mohadevpur	0.57	0.71	Poor
22	Naogaon	0.48	0.90	Average
23	Narayangonj	0.13	0.91	Good
24	Nayarhat	0.12	0.91	Good
25	Rajshahi	0.19	0.97	Average
26	Serajgonj	0.09	0.95	Good
27	Sheola	0.39	0.66	Average
28	Sunamgonj	0.20	0.83	Average
29	Sylhet	0.23	0.78	Poor
30	Taraghat	0.18	0.90	Good
31	Tongi	0.07	0.98	Good

Table 4. 4: Statistics for 72- hour forecast performance

Sl. No.	Station	MAE (m)	r2	Performance
1	Aricha	0.14	0.96	Good
2	Bahadurabad	0.28	0.81	Good
3	Bhagyakul	0.10	0.97	Good
4	Bhairabbazar	0.11	0.96	Good
5	Bhusirbandar	0.91	0.42	Very Poor
6	Bogra	0.51	0.57	Not satisfactory
7	Chakrahimpur	0.46	0.68	Not satisfactory
8	Chilmari	0.31	0.76	Average
9	Demra	0.13	0.92	Average
10	Dhaka	0.14	0.88	Good
11	Goalondo	0.13	0.96	Good
12	Gorai-RB	0.17	0.97	Average
13	Hardinge-BR	0.20	0.97	Average
14	Jagir	0.15	0.48	Average
15	Jamalpur	0.25	0.91	Good
16	Kaunia	0.14	0.96	Average
17	Kamarkhali	0.27	0.37	Not satisfactory
18	Mirpur	0.11	0.94	Good
19	Moulvibazar	0.47	0.35	Very Poor
20	Mymensingh	0.26	0.92	Not satisfactory
21	Mohadevpur	0.80	0.59	Not satisfactory
22	Naogaon	0.68	0.83	Not satisfactory
23	Narayangonj	0.18	0.85	Good
24	Nayarhat	0.16	0.89	Good
25	Rajshahi	0.29	0.96	Average
26	Serajgonj	0.18	0.88	Good
27	Sheola	0.56	0.45	Not satisfactory
28	Sunamgonj	0.30	0.69	Not satisfactory
29	Sylhet	0.34	0.63	Average
30	Taraghat	0.25	0.87	Good
31	Tongi	0.09	0.96	Good

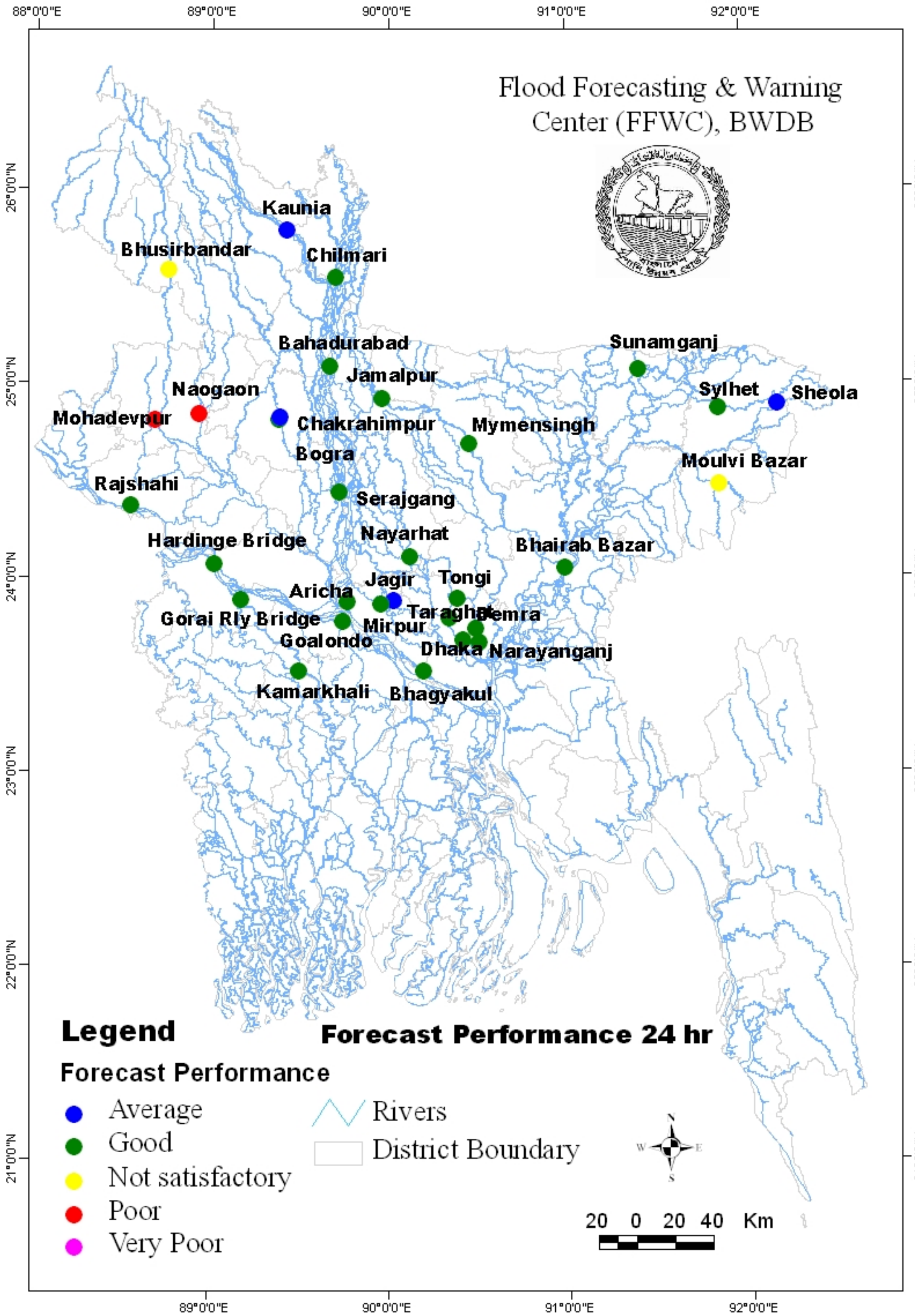


Figure 4. 1: 24 hr Forecast Evaluation (Year, 2012)

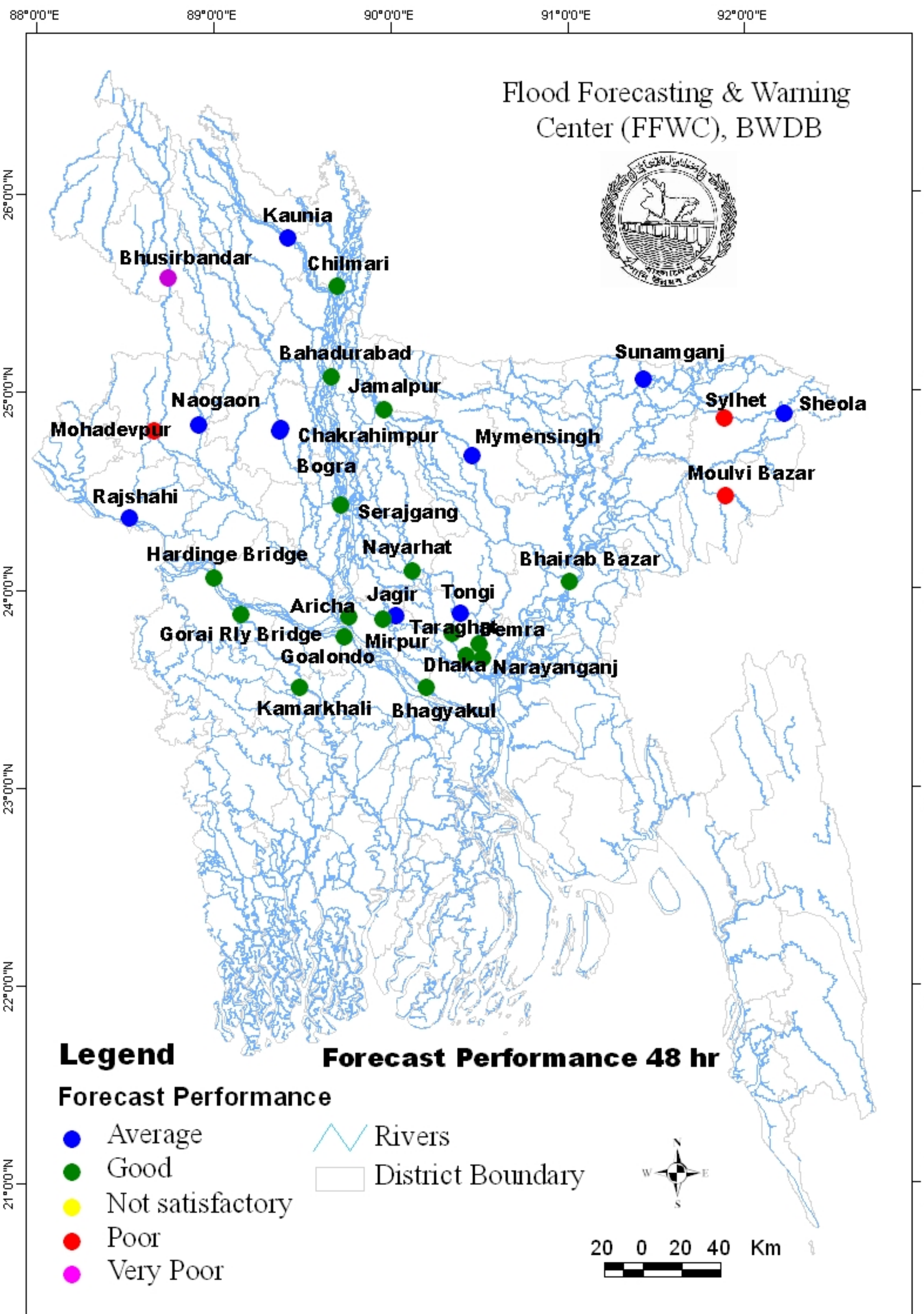


Figure 4. 2: 48 hr Forecast Evaluation (Year, 2012)

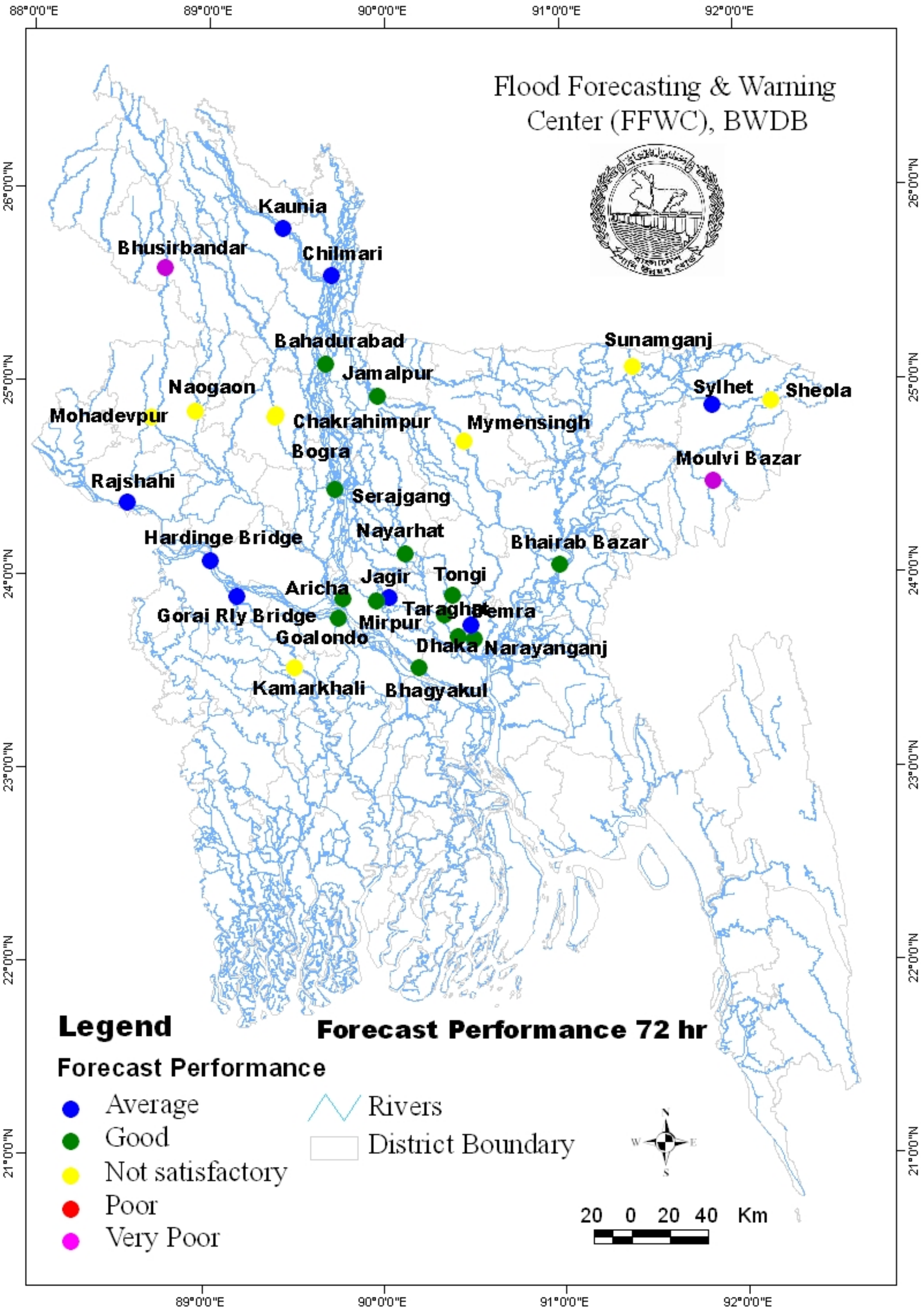


Figure 4. 3 : 72 hr Forecast Evaluation (Year, 2012)

4.4.2 Medium Range (upto 10-days) Probabilistic Forecast Performance

CFAN (Climate Forecast Application Network) utilizes ECMWF (European Centre for Medium-Range Weather Forecasts) weather prediction data in their model to generate 51 sets of ensemble discharge forecasts data on the Brahmaputra at Bahadurabad and on the Ganges at Hardinge-Bridge in Bangladesh. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions. The customized FFWC model used for the flood forecasting of extended lead-time (medium range upto 10-days) using climate forecast application data has been named CFAB-FFS (CFAB Flood Forecasting Study) model.

In addition to existing 24, 48 & 72 hrs deterministic forecast, CFAN model generates medium range 10 days lead-time probabilistic forecasts for mean, upper bound and lower bound WL at 18 locations listed below in experimental basis. The Mean Water Level forecast made from the mean discharge and the mean rainfall forecast of all 51 ensemble series. The Upper bound and Lower bound water corresponds to +1 standard deviation from the mean and -1 standard deviation from the mean respectively.

The statistics of forecast performance for the stations inside Bangladesh have been presented through Table 4.5 to Table 4.8. These tables and indicate the performance forecasts at individual stations for upto 10-days period.

Table 4. 5 : Performance of 3-day Probabilistic Forecast

Stations	Standard Deviation(-1)			Mean			Standard Deviation(+1)		
	MAE(m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2
Aricha	*0.16*	*0.21*	*0.76*	*0.13*	*0.18*	*0.76*	*0.19*	*0.24*	*0.75*
Bhagyakul	*0.12*	*0.16*	*0.73*	*0.12*	*0.15*	*0.73*	*0.17*	*0.20*	*0.71*
Bhairabbazar	*0.12*	*0.15*	*0.88*	*0.12*	*0.15*	*0.88*	*0.11*	*0.15*	*0.88*
Demra	*0.13*	*0.16*	*0.69*	*0.13*	*0.16*	*0.69*	*0.13*	*0.16*	*0.69*
Dhaka	*0.13*	*0.16*	*0.76*	*0.13*	*0.16*	*0.76*	*0.13*	*0.15*	*0.76*
Goalondo	*0.23*	*0.32*	*0.88*	*0.25*	*0.31*	*0.89*	*0.37*	*0.43*	*0.89*
Gorai-RB	*0.13*	*0.18*	*0.79*	*0.13*	*0.16*	*0.81*	*0.20*	*0.23*	*0.79*
Kamarkhali	*0.20*	*0.30*	*0.69*	*0.25*	*0.34*	*0.63*	*0.34*	*0.43*	*0.61*
Mirpur	*0.10*	*0.13*	*0.75*	*0.10*	*0.13*	*0.75*	*0.10*	*0.13*	*0.75*
Mohadevpur	*0.43*	*0.69*	*0.68*	*0.43*	*0.69*	*0.68*	*0.43*	*0.69*	*0.68*
Moulvibazar	*0.45*	*0.64*	*0.00*	*0.45*	*0.64*	*0.00*	*0.45*	*0.64*	*0.00*
Naogaon	*0.50*	*0.70*	*0.73*	*0.50*	*0.70*	*0.73*	*0.50*	*0.70*	*0.73*
Serajgonj	*0.27*	*0.33*	*0.56*	0.78	0.32	0.98	*0.26*	*0.36*	*0.52*
Sheola	*0.09*	*0.12*	*0.76*	1.65	0.48	0.96	*0.09*	*0.12*	*0.76*
Sherpur	*0.46*	*0.55*	*0.35*	0.62	0.34	0.99	*0.46*	*0.55*	*0.35*
Sunamgonj	*0.22*	*0.34*	*0.71*	0.36	0.11	0.87	*0.22*	*0.34*	*0.71*
Sylhet	*0.23*	*0.29*	*0.78*	0.97	0.26	0.95	*0.23*	*0.29*	*0.78*
Tongi	*0.09*	*0.11*	*0.79*	0.18	0.06	1.55	*0.09*	*0.11*	*0.79*

Table 4. 6: Performance of 5-day Probabilistic Forecast

Stations	Standard Deviation(-1)			Mean			Standard Deviation(+1)		
	MAE(m)	RMSE(m)	R2	MAE(m)	RMSE(m)	R2	MAE(m)	RMSE(m)	R2
Aricha	0.30	0.36	0.42	0.21	0.26	0.44	0.27	0.34	0.43
Bhagyakul	0.21	0.27	0.42	0.16	0.22	0.43	0.26	0.31	0.42
Bhairabbazar	0.16	0.20	0.79	0.15	0.19	0.78	0.14	0.19	0.78
Demra	0.17	0.21	0.52	0.17	0.21	0.52	0.17	0.21	0.52
Dhaka	0.17	0.22	0.59	0.17	0.21	0.59	0.17	0.20	0.59
Goalundo	0.44	0.60	0.58	0.47	0.55	0.62	0.58	0.65	0.73
Gorai-RB	0.27	0.33	0.44	0.18	0.24	0.48	0.26	0.33	0.50
Kamarkhali	0.43	0.55	0.30	0.48	0.57	0.30	0.61	0.71	0.28
Mirpur	0.15	0.20	0.54	0.15	0.19	0.53	0.14	0.18	0.53
Mohadevpur	0.46	0.61	0.77	0.46	0.61	0.77	0.46	0.61	0.77
Moulvibazar	0.63	0.79	0.02	0.63	0.79	0.02	0.63	0.79	0.02
Naogaon	0.69	0.90	0.56	0.69	0.90	0.56	0.69	0.90	0.56
Serajgonj	0.47	0.53	0.41	0.30	0.38	0.44	0.28	0.40	0.40
Sheola	0.13	0.16	0.59	0.13	0.16	0.59	0.13	0.16	0.59
Sherpur	0.62	0.73	0.11	0.62	0.73	0.11	0.62	0.73	0.11
Sunamgonj	0.33	0.48	0.49	0.33	0.48	0.49	0.33	0.48	0.49
Sylhet	0.35	0.44	0.55	0.35	0.44	0.55	0.35	0.44	0.55
Tongi	0.13	0.16	0.66	0.13	0.16	0.65	0.13	0.16	0.65

Table 4. 7: Performance of 7-day Probabilistic Forecast

Stations	Standard Deviation(-1)			Mean			Standard Deviation(+1)		
	MAE(m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2
Aricha	0.43	0.51	0.41	0.25	0.29	0.46	0.26	0.35	0.48
Bhagyakul	0.28	0.36	0.44	0.17	0.21	0.47	0.28	0.32	0.48
Bhairabbazar	0.19	0.25	0.69	0.18	0.24	0.69	0.17	0.22	0.68
Demra	0.22	0.26	0.39	0.21	0.26	0.39	0.20	0.25	0.39
Dhaka	0.20	0.27	0.52	0.19	0.24	0.51	0.18	0.22	0.50
Goalondo	0.55	0.68	0.41	0.56	0.62	0.51	0.69	0.78	0.35
Gorai-RB	0.36	0.44	0.45	0.20	0.25	0.50	0.29	0.35	0.54
Kamarkhali	0.58	0.72	0.11	0.65	0.76	0.08	0.78	0.91	0.11
Mirpur	0.18	0.23	0.60	0.17	0.21	0.47	0.16	0.20	0.61
Mohadevpur	0.55	0.75	0.66	0.55	0.75	0.66	0.55	0.75	0.66
Moulvibazar	0.73	0.90	0.02	0.73	0.90	0.02	0.73	0.90	0.02
Naogaon	0.82	1.00	0.49	0.82	1.00	0.49	0.82	1.00	0.49
Serajgonj	0.68	0.74	0.56	0.39	0.44	0.57	0.28	0.36	0.52
Sheola	0.18	0.22	0.30	0.18	0.22	0.30	0.18	0.22	0.30
Sherpur	0.74	0.91	0.00	0.74	0.91	0.00	0.74	0.91	0.00
Sunamgonj	0.42	0.60	0.29	0.42	0.60	0.29	0.42	0.60	0.29
Sylhet	0.77	0.56	0.33	0.77	0.56	0.33	0.77	0.56	0.33
Tongi	0.16	0.20	0.56	0.16	0.20	0.54	0.16	0.20	0.53

Table 4. 8: Performance of 10-day Probabilistic Forecast

Stations	Standard Deviation(-1)			Mean			Standard Deviation(+1)		
	MAE (m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2
Aricha	*0.60*	*0.69*	*0.35*	*0.30*	*0.36*	*0.39*	*0.32*	*0.41*	*0.35*
Bhagyakul	*0.45*	*0.54*	*0.39*	*0.20*	*0.26*	*0.42*	*0.32*	*0.37*	*0.41*
Bhairabbazar	*0.28*	*0.36*	*0.55*	*0.27*	*0.33*	*0.44*	*0.25*	*0.32*	*0.47*
Demra	*0.28*	*0.35*	*0.28*	*0.26*	*0.33*	*0.27*	*0.25*	*0.31*	*0.26*
Dhaka	*0.30*	*0.38*	*0.31*	*0.24*	*0.32*	*0.31*	*0.22*	*0.29*	*0.28*
Goalondo	*0.74*	*0.98*	*0.28*	*0.62*	*0.71*	*0.43*	*0.86*	*0.93*	*0.57*
Gorai-RB	*0.54*	*0.65*	*0.34*	*0.24*	*0.32*	*0.42*	*0.35*	*0.42*	*0.43*
Kamarkhali	*0.74*	*0.93*	*0.01*	*0.70*	*0.86*	*0.04*	*0.98*	*1.13*	*0.06*
Mirpur	*0.27*	*0.34*	*0.51*	*0.23*	*0.28*	*0.36*	*0.20*	*0.25*	*0.48*
Mohadevpur	*0.52*	*0.71*	*0.66*	*0.52*	*0.71*	*0.66*	*0.52*	*0.71*	*0.66*
Moulvibazar	*0.80*	*0.96*	*0.01*	*0.80*	*0.96*	*0.01*	*0.80*	*0.96*	*0.01*
Naogaon	*0.97*	*1.12*	*0.38*	*0.97*	*1.12*	*0.38*	*0.97*	*1.12*	*0.38*
Serajgonj	*0.86*	*0.92*	*0.65*	*0.43*	*0.52*	*0.64*	*0.32*	*0.38*	*0.51*
Sheola	*0.25*	*0.31*	*0.22*	*0.25*	*0.31*	*0.22*	*0.25*	*0.31*	*0.22*
Sherpur	*0.80*	*1.08*	*0.04*	*0.80*	*1.08*	*0.04*	*0.80*	*1.08*	*0.04*
Sunamgonj	*0.52*	*0.67*	*0.12*	*0.52*	*0.67*	*0.12*	*0.52*	*0.67*	*0.12*
Sylhet	*0.49*	*0.69*	*0.12*	*0.49*	*0.69*	*0.12*	*0.49*	*0.69*	*0.12*
Tongi	*0.22*	*0.28*	*0.54*	*0.22*	*0.28*	*0.49*	*0.22*	*0.28*	*0.45*

CHAPTER 5 : INUNDATION STATUS

The country as a whole experienced normal flooding during the monsoon-2012. The flood during 2012 was not a severe one and stayed for short (1-day) to medium duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin, except Jhikorgacha on Kobodak of the south west part of the country. The South Western part of the country experienced prolong flooding in few stations longer than the previous flood years, specially part of Khulna, Jessore and Satkhira districts. Water Level at Jhikorgacha on Kobodak was flowed above the danger level for continuous 49 days. During the monsoon-2012 there were flash floods affecting the Jariajanjail (in the North east, in Netrokona district) and par to f Bandarban-Coxs Bazar(South east).

Out of 23 Water Level (WL) monitoring stations in the Brahmaputra basin, at 10 stations WL was crossed the respective DLs, these are Ghagot at Gaibandha for 15 days, Jamuna at Bahadurabad for 24 days and Serajgonj for 10 days and Lakhya at Narayanganj during July, August and September. Other stations flowed above DL are Noonkhawa and Chilmari on Brahmaputra, Aricha on Jamuna, Badargonj on Jamunaeswari, Kurigram on Dharala, and Dalia on Teesta. As a result, low-lying areas of Kurigram, Lalminiorhat, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur and Narayangonj districts were flooded for short (2-days) to medium periods (24 days).

In the Ganges basin out of 22 WL monitoring stations, at 4 stations river exceeded their respective DLs during monsoon 2012, these are Goalondo on Ganges/ Padma, Bhagyakul on Padma, Mohadevpur on Atrai (Noagaon District) and Jhikorgacha on Kobodak during the monsoon 2012. Total 4 WL monitoring stations of the Ganges basin crossed the DLs during the monsoon 2012. The WL of river Padma at Bhagyakul was flowed for 11 days above DL. The low lying areas of Rajbari, Faridpur, Manikgonj, Munshigonj, Sariatpur and Noagaon districts was affected by normal flooding during the month of June and August. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul WL gauge stations. Prolong flooding situation was prevailing in part of Satkhira, Khulna and Jessore districts due to very poor drainage condition along with very high rainfall during August. The WL of Kobodak river at Jhikorgacha flowed above the DL for continuous 49 days. Flood caused immense suffering of the people of the locality.

Out of 20 WL monitoring stations in the Meghna basin, at 14 stations flowed above their respective DLs, these are Kanaighat, Sylhet and Sunamgonj on Surma River, Amalshid, Sheola and Sherpur Kushyara River, Jariajanjail on Kangsa, Mouolvi Bazar and Manu Rail Bridge on Manu river, Habigonj and Bullah on Khowai river, Kamalgonj on Dhalai river, Durgapur on Someswari river and Nakuakaon on Bhugai river for 1 day (Manu at

Manu Railway Bridge) to 35 days (Kangsha at Jariajanjail – Netrokona Districts, caused moderate duration of flooding). As a result, floods of short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, and Habigonj during the monsoon 2012. .

In the South Eastern Hill basin WL of the rivers Muhuri, Halda, Matamuhuri and Snagu crossed their respective DLs for 1 to 8 days during this monsoon-2012. As a result, a short duration flood occurred at Narayanhat (Halda river), Bandarban(Sangu river), Dohazari (Sangu river) Chiringa (Matamuhuri river) and Lama (Matamuhuri river) during the monsoon 2012. Total 7 WL monitoring stations in the South Eastern Hill basin crossed DLs during the Monsoon-2012. As a result, a flood of short duration was experienced in the districts of Chittagong, Bandarban and Cox's Bazar.

In flood period, Flood Inundation Map has been developed at FFWC as a part of routine output based on the result file/data of the Flood Forecasting Model and digital elevation map (DEM). This was done by using MIKE 11 FF module and GIS, where the results were found from MIKE 11 Rainfall-Runoff and Hydrodynamic modelling simulation. In addition to that rainfall surface of Situation Map for past 24 hours has also been developed in the FFWC on routine basis. Flood inundation for whole country is a macro level product showing a general overview of flood situation of the whole country. A detail and authentic DEM shall improve significantly showing inundation status map. Sample of Flood Inundation Maps based on 24 hour and 48 hours forecast respectively are presented in the following pages (Fig 5.1 and Fig 5.2).

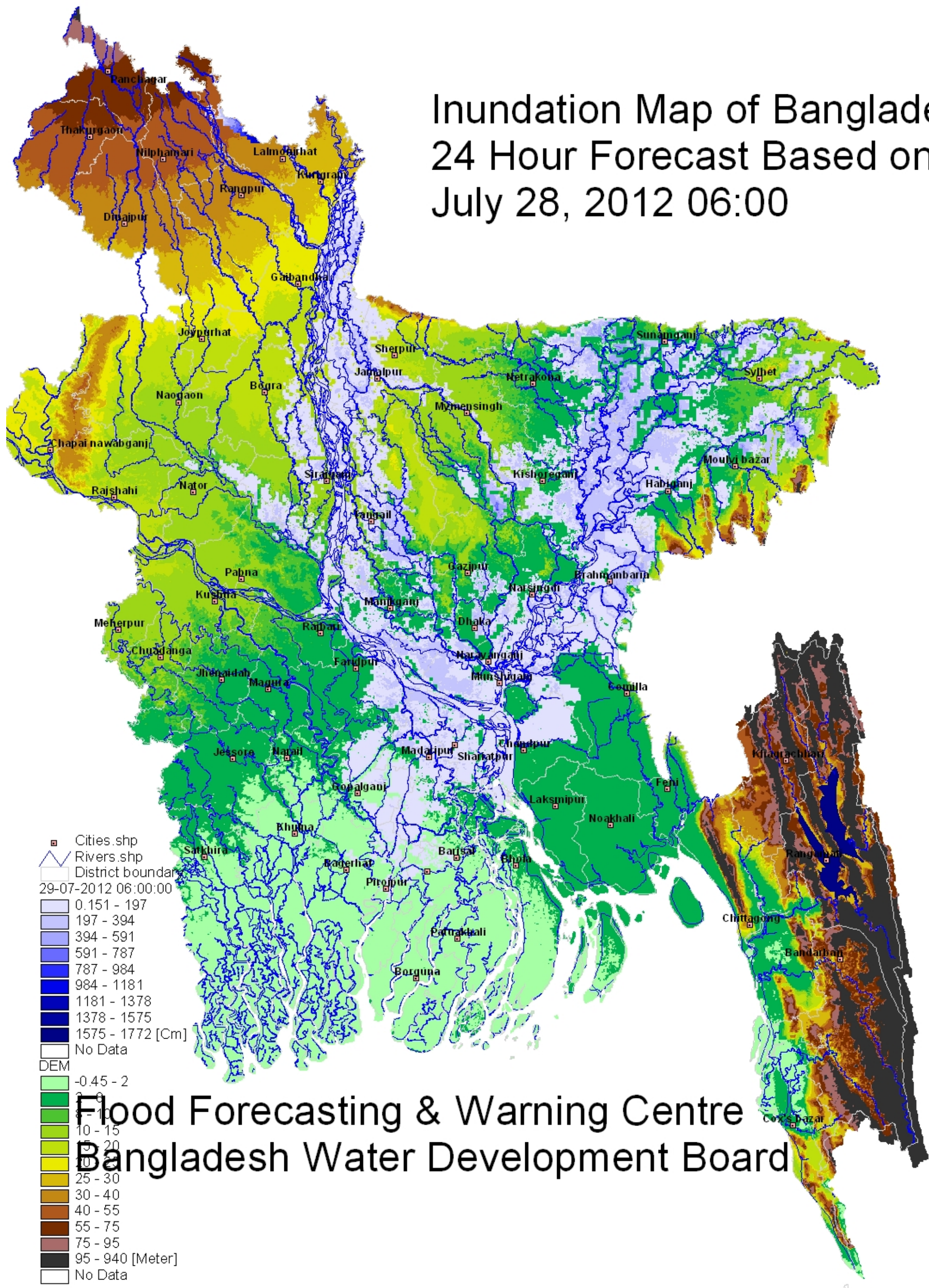


Figure 5. 1: Flood Inundation Map of Bangladesh (24hr Forecast 28 July 2012)

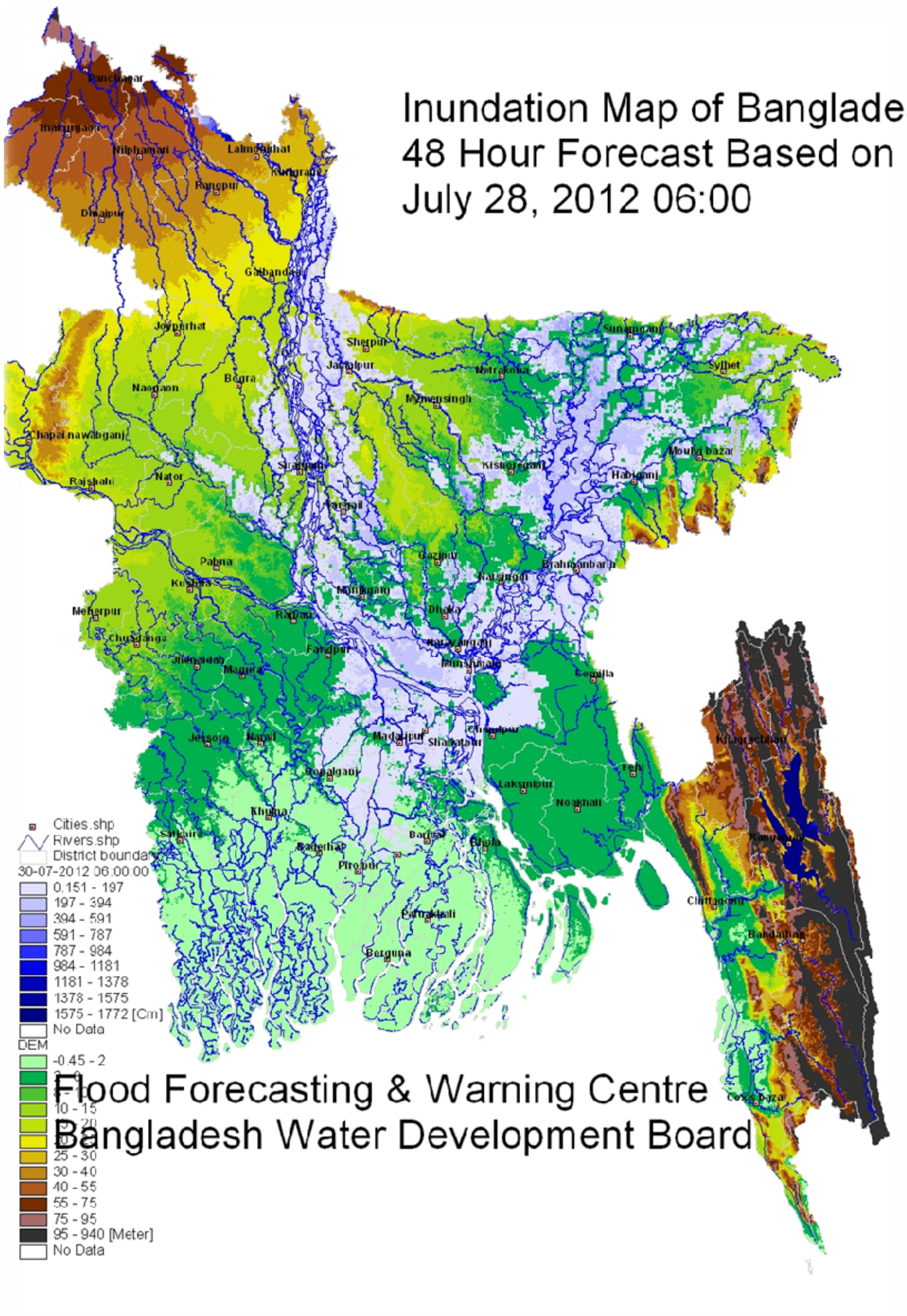


Figure 5. 2 : Flood Inundation Map of Bangladesh (48hr Forecast Based on 28 July 2012)

CHAPTER 6: CONCLUSIONS

The flood problem in Bangladesh is extremely complex. The country is an active delta; it has numerous networks of rivers, canals and coast creeks with extensive flood plains through which surface water of about 1.7 million sq-km drains annually. The annual average rainfall of about 2300 mm, the range varies from about 1500 mm in the north-west to over 5000 mm in the north-east. Flood occurs in Bangladesh almost every year and devastating ones in every 5 to 10 years.

Floods are normal monsoon phenomena in the deltaic plains of Bangladesh. Although the livelihood of the people in Bangladesh is well adapted to normal monsoon flood, the damages due to inundation, riverbank erosion or breach of embankment, etc. still occur in various regions in almost every monsoon season. They often have disastrous consequences: major damage to infrastructure, great loss of property, crops, cattle, poultry etc, human suffering and impoverishment of the poor. With every major flood in Bangladesh, food security and poverty situation adversely affected.

The runoff from GBM catchments of about 1.76 million sq-km passes through the intricate network of river systems of Bangladesh where only 7% area lies within the country. The characteristic of river varies from river to river and differs from region to region. Usually, in the Brahmaputra basin, flood begins in the late June while in the Ganges basin it starts from the second half of July. In the Meghna and South-Eastern Hill basins, flash flood occurs at the beginning of monsoon or even pre-monsoon causing loss of crops and source of hardship for the population.

As mandated, FFWC of BWDB under Ministry of Water Resources monitored the flood situation during the monsoon and also beyond the monsoon if situation demand. The FFWC has issued daily flood bulletin from May to October with a forecast lead-time of 24hrs, 48hrs and 72hrs along with warning messages and flood inundation maps.

In addition to 24hrs, 48hrs & 72 hrs deterministic flood forecasts, FFWC issued medium range 10 days lead-time probabilistic forecasts at 18 locations in experimental basis with the technical support from RIMES utilizing ECMWF weather prediction data over the GBM basin to generate 51 sets of ensemble discharge forecasts on the Brahmaputra at Bahadurabad and on the Ganges rivers at Hardinge-Bridge. Technical support from the RIMES-Thailand (Regional Integrated Multi-hazard Early Warning System) is recognized for preparing and providing the medium range 10-day lead time probabilistic flood forecast in Bangladesh on experimental basis. This was initiated under CFAN projects with assistance from USAID. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions.

The FFWC also issued special type of flood bulletin during the critical time and tried to disseminate the whole situation to the people of the country through different mass media, news agencies, e-mail, web site and Cell Broadcast through Teletalk mobile phone. The Cell Broadcast is a new way of dissemination started from July 2011, in cooperation of DDM, anyone can call in 10941 number from Teletalk mobile and hear a short voice message in Bangla. The information has been used by various organizations: national and international disaster management operators, many Government agencies, NGOs and BWDB itself.

However, due to different shortcomings including limited upstream hydro-meteorological information, detail & accurate digital elevation model (DEM) and limited technological development of the center itself, the services were fully not satisfactory to all corners. Area-inundation forecast have been indicative, based on a coarse DEM and old topographic maps. Information on flash flood was limited due to technological limitation and non-availability of the real time data at a much shorter interval than the usual.

The continued achievement of the FFWC is notable. It is trying hard to overcome the limitations and realities. Regional models need to have developed to provide regional flood forecasting and warning. Moreover, flood inundation map needs to develop further.

Activity has been initiated to extend the deterministic flood forecast lead time upto 5-days from present 3-days and expand the deterministic flood forecast to few selected BWDB projects with support from Comprehensive Disaster Management Programme (Phase –II) under Ministry of Food & Disaster Management.

The FFWC of BWDB took the privileged to reflect the flood situation as accurate and reliable as possible. All these combined efforts may have played an effective role in minimizing people sufferings and damages of the infrastructures during the flood of 2012.

As a whole the flood of 2012 was fairly normal compare to devastating flood of 1987, 1988, 1998, 2004 and 2007. The maximum flooded area was 12% of the whole country (17,700 sq-km approximately).

Evaluation indicated that, the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2012 on Major River flood forecasting is around 92%, 85% and 79% accurate for 24hrs, 48hrs and 72 hrs lead time respectively. Flood forecast model, the "*Super Model*" based on MIKE-11FF showed better performance in Brahmaputra and Ganges basins while in the flash flood areas, the model performance needs to improve further.